E/CONF.39/A/336
5 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A

Romania

THE INVENTORYING OF THE NATURAL RESOURCES AND COORDINATED ACTION FOR THE BETTER EXPLOITATION OF VARIOUS TYPES OF RESOURCES

By Costin MURGESCU,
Deputy Director of the Institute
of Economic Research
of the Romanian People's Republic Academy

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

THE INVENTORYING OF THE NATURAL RESOURCES AND COORDINATED ACTION FOR THE BETTER EXPLOITATION OF VARIOUS TYPES OF RESOURCES

No.882

A.

Costin Murgescu, Deputy Director of the Institute of Economic Research of the Romanian People's Republic Academy.

The Importance of inventorying the natural resources

1. The speeding up of the industrial development is today ofor all under-developed countries, a fundamental necessity on the carrying out of which depends the diversification of their national economy, the growth of the economic potential, and as a consequence, the raising of the income per capita. It is absolutely clear for us that the desire expressed in resolution Nr.1710 (XVI) of the U.N.O. General Assembly , to see the underdeveloped countries achieve, at the end of this decade, an annual rate of increase of the total national income by at least 5 per cent would be unreal without a sustained policy of industrialization.

2. In order to ensure a full and rational utilization of the natural and man-power resources of each country, the plans or programmes of industrialization must be based on as detailed as possible knowledge of these resources. The scientific inventorying of the natural resources is an essential pre-requisite - in connection especially with the long term planning - for the efficient guiding of the main lines of development, for the determination of a corresponding structure of investments in keeping with the industrial branches and sub-branches for which the most part of the efforts must be made.

3. Accepted in theory, the implementation of this condition is sometimes under-estimated in the practice of the drawing up of the industrialization programmes. One of the reasons of this under-estimation is the opinion that the present level of information about the natural resources offers a sufficient basis for determining the political directions of industrialization. But, if no country proceeds from nil as regards the level of knowledge of its natural resources, it is not less true that very many do not know in detail these resources and possibilities. The same conditions have determined the underdevelopment, and also a low level of information of the respective resources. We shall mention in this respect the experience of Romania. In the period between the two world wars, Romania was sixth among the oil producing countries of the world; the exploitation of oil, however ,was especially carried on only in a limited zone, about which the experts asserted that it was going to be exhausted so that in 1936 it was estimated that Romania's reserves could ensure the production for only 10 to 15 years. The removal of the foreign monopolies and the taking over by the state - in 1948 - of the prospection and exploration works , have led to the discovery of new deposits either in completely new regions, or at greater depths, under the layers previously exploited. The annual crude oil production could thus be raised in 1961 by about 5 million tons as against 1938, the new producing regions and the deposits discovered after 1948 giving about 85 per cent , of the total quantity of crude oil being extracted today.

4. The importance of inventorying the natural resources for laying the basis of the plans of industrialization does not at all imply the subordination of the beginning of industrialization to the complete carrying out of industrialization. The inventorying of the natural resources arouses numerous problems. necessitates materials means, cadres and time. To postpone the urgent work of industrialization until the carrying out of this operation would practically mean to enter a vicious circle and condemn the under-developed regions to stagnation. The solving of these two problems must be achieved at the same time, they should complete each other during their evolution supporting each other. If the present level of knowledge of the natural resources is not sufficient, in most countries, for laying the basis of the industrial lization plan, it nevertheless offers the possibility of establishing the main directions of developing industrialization, the inventorying operation having to expand and render these directions in detail. In fact, inventorying itself must be conceived as a permanent action considering the possibilities constantly being created by the progress of science and technique either for drawing new resources into the economic circuit, or for new turning to account of the known resources.

The conditions of inventorying the natural resources

5. An important condition is that the action of inventorying the natural resources unfold in an efficient way and in keeping with the requirements of the speeding up of industrial development, refers to the setting up and consolidation of the permanent sovereignity of each people over the riches and natural wealth in their country. Historic experience has shown that on the extent to which this national sovereignity is ensured, depends the possibility of each country to remove the economic, political and juridical obstacles which prevent not only the rational turning to account of its natural resources, but even the action of inventorying them.

6. The inventorying of the natural resources being carried out on a national scale and in a coordinated way, the role of the state in the economic life and the means it possesses will directly determine the ampleness and efficiency of each action undertaken in this respect. In Rumania, for instance, the setting up of the state property - as property of the entire people - over all the resources of the subsoil, waters, etc. has played a decisive role in the subsequent broad unfolding of the inventorying work.

7. The inventorying of the natural resources raises complex problems on the successful solving of which depends the way in which it is organized In Rumania, the activity carried on in this direction is organically integrated in the plan for the development of the national economy, a fact which enables both the permanent correlation of the research work with the current and future requirements of industrial development and the ensurance of the material and financial means and cadres necessary for the inventorying action.

8. The directions of inventorying are of course many-sided: their number grows in relation to the variety of the resources of the respective country It is difficult, however, to suppose that a country in the initial stage of industrialization could in a rational way, undertake the inventorying action in all possible directions and with equal intensity. The hierarchization and placing at intervals of the directions of inventorying are not achieved on the basis of an abstract outline, but must be determined in a planned way in relation to the specific conditions of the country and the fundamental targets of the plan of industrialization in the respective period of time. In Rumania, for instance, one of the main problems raised during the transition to socialist industrialization lay, on the one hand, in the unsatisfactory level of the pro-

duction of electric power, and on the other, in the irrational structure of the natural resources of electric power used in this branch. This situation led to the fact that one of the main directions of the inventorying action referred to the country's electric power resources, in view of establishing the possibilities of developing the electric power output by the utilization of hydroelectric power resources of the country, with a view to establishing the possibilities of developing the production of electric power by the use of the hydroelectric power resources and inferior fuels. The results of the research work carried on and discussed in detail at the Academy of the Romanian People's Republic have been used in the drawing up of the ten-year electrification plan of the country, achieved during the years 1951-1960. The afore-mentioned example has a certain general value since under the conditions of modern technique, electrification must be a step before industrialization; the implementation of this requirement imposes the granting of priority to the inventorying of the electric power resources in the placing at intervals of the order of operations by taking into account their urgency.

9. Conceived as an integral part of the programme of industrialization, the action of inventorying the natural resources cannot be limitted to the stage of the finding out and valuation. At the same time it implies the depending of the study by laying the technical economic basis of the possibilities of the optimum utilization of the respective resources. Without this, the use of the results of inventorying in the drawing up of the programme of development of various industrial branches becomes impossible.

10. The practical implementation of the inventorying of the natural resources in the established directions is indisolubly linked to the training of the cadres of necessary experts, also to the organization of a system of research institutes and organisms with precisely determined profile, tasks and attributions. Knowing the significance of this problem, we think it absolutely useful that the institutes of economic development and planning, now being set up in certain countries that are now developing, in keeping with the recommendations of resolution 1708 (XVI) of the U.N.O. General Assembly - should grant due attention to creation of the necessary prerequisites for the drawing up of certain plans of scientific study of the natural resources.

11. No matter how well conceived, any plan of inventorying the natural resources becomes futile if, in its implementation neither the technical basis, nor the corresponding financial means are ensured. The allocation to this purpose of an important quota from the investments allotted by the state for the economy, is one of the explanations for the achievements obtained by the Romanian People's Republic in this field. Thus, between 1950 and 1961, to an increase of the crude oil output of nearly 2.4 times, the industrial reserves increased three times; there are similar situations with the other subsoil resources. The plan for the years 1960-1965 providing for the further increase of extraction, at the same time envisages the considerable growth of the industrial reserves at all the categories of subsoil resources.

12. Some foreign commentators try to explain these successes of the Romanian People's Republic exclusively through the angle of the natural resources of the country. We believe that such an explanation cannot help us understand the problem under discussion. It would be more adequate to take into account the fact that between 1954 and 1959 the investments of the Romanian state only for geological research work amounted to eight thousand million lei, that is over 16 per cent of the total volume of industrial investments. In the present Six Year Plan(1960-1965) 12 thousand million lei are allotted for geological research, that is about 12 per cent of the total of envisaged industrial investments.

13. The specific weight of the investments made for the inventorying of the

natural resources inevitably varies in keeping with the specific conditions of each country and with the concrete objectives established by it in the industrial development. What seems to us essential, is that these investments should concurrently enable : the expansion of the basis of raw materials of the country required by the development of all the industrial branches for which there are favourable natural conditions and the increase of reserves over a longer period of time in the conditions of the growth of extraction.

Organization of inventorying the natural resources in Rumania

14. Characteristic of the system of organization of the inventory action in Rumania is the close cooperation between:

- the scientific research institutes of the Rumanian People's Republic Academy called on to solve the fundamental theoretical problems of the inventorying and turning to account of the various resources;

- the research institutes under the economic ministeries and departments, where research work is continued in the field of designing and economic substantiation ;

- the ministeries and departments which turn to good account the respective resources ;

- the central organs of coordination and planning.

15. The forms underwhich this cooperation is achieved varies in accordance with the field and problem being solved. Sometimes, the cooperation is the result of a common plan target achieved by each and every institution in a longer period of time in keeping with their specific attributions ; other times, the cooperation is achieved as part of a collective or of a mixed commission with a temporary character. What seems to us essential is that the system of organization should:

- ensure the convergence of all activities unfolded in the respective domain for the practical solution of the problem imposed to the national economy by the requirements of a rational turning to account of the natural resources;

- exclude parallelism in work, which could lead to a waste of efforts and rise the cost of inventory work.

16. As the way in which this system functions in the field of inventorying and fully using the waters is presented in a separate paper, at item A 4.1.2 of the agenda of the present Conference, we shall hereby present the way in which the same system functions in the field of inventorying subsoil resources.

17. In the field of the subsoil resources, participating in the action of inventorying and valuation, is the Geological Committee under the Council of Ministers, as an all-country coordinating forum of the geological activity on the one hand, and on the other, are the ministeries responsible for the exploitation of the respective resources (The Ministry of Oil and Chemistry, the Ministry of Mines and Electric Power, etc.)

18. The operations of geological and mining prospection and exploration are carried out in specialized units belonging either to the Geological Committee, or to the above mentioned ministeries. The enterprises of the Geological Committee carry on geological research work in new zones all over the country, while the ministeries carry out work in the perimetres on the zones under exploitation, and for their extensions

19. a) The operations of inventorying the reservesof mineral substances

are based on precise geological researches made on topographical maps at the level of present-day technique which are drawn up by aerophotogrametric surveys. Through the faithful rendering of the physiographic pecularities of the soil, the maps drawn up by aerophotogrametric surveys can be successfully used also in the sorting of the land degraded by soil erosion, in the sorting of the soil falling in, etc., and can serve as basis for the study of the soil in connection with the hydro-energetic meliorations.

b) The general geological survey is followed by the geological prospections at bigger scales (the scale 1:2o,ooo - 1:1o,ooo - 1:2,ooo)which aim at recording all the appearances of useful mineral substances met in natural outcrops or by small outcrop operations (ditches, trenches).

c) The geophysical prospections by various methods (seismics, gravimetrics, magnetometrics, electrometrics, radiometrics, etc.) are recommended to be carrying out both for completing the geological prospections in regions with natural outcrops, and for studying the regions without such outcrops. One can apply in certain cases, also the geo-chemical prospection, for studying the possibilities of extension in depth of certain deposits of ores and hydro-carbides (oil and gases).

d) By applying the results of the geological and geophysical prospections, special departments carry on exploration work, through drillings for hydro-carbides and by mining operations and drillings for ores.

e) The operations of prospections and explorations lead first of all, to the discovery of C2 geological reserves, and through the making denser of explorations one can achieve the outlining of the C1 projection reserves. Chemical and optical analyses are made in laboratories of chemistry and petrography endowed with modern apparatuses ,om the tests systematically gathered during the exploration operations, in order to determine the content of the useful mineral substances discovered, and for turning them in this way into reserves of the B category.

f) Only after the carrying out of these operations, can one pass on, on the basis of the reserves homologated by a special commission, to the projection and opening of exploitation work.

g) At the same time, with a view to increasing the economic efficiency of the prospection and exploitation operations, one should take into account the fact that, in keeping with the existing possibilities, the exploration of the mineral resources could further be used for exploitation purposes. To this aim, the dimensions used in the exploitation are considered in the designing of the network of the main operations, as regards the distance between the horizon of exploitation, the distance between the vertical or slanted operations and the digging profile.

2o. The action of identifying the wood resources - led by the Ministry of Forestry Economy, under the subordination of which there are a number of institutes of forestry research, studies and designs - has the following objectives: the determinations of the growth of tree per years, species and zones; the establishing of the conditions of territorial location and in time of the cutting areas; the establishing of the best conditions for forest planning for exploitation and replanting of the exploited cutting areas, etc.

21. a) In the field of agriculture, the main inventorying action was synthetized in the study regarding the division into zones of agricultural output, the aim of which is to reach an as efficient and rational as possible utilization of the land.

b) In its first stage , carried on under the guidance of the Rumanian People's Republic Academy, the study comprised the analysis of the natural and economic conditions in our country in relation to the requirements of each production branch, and concluded with an economic study of the production zones. The researches regarding the problems connected with the natural framework of production, that is the climatic geomorphological and soil conditions, have synthetized the characteristic elements and put them down in the plans of the regions at the scale 1:500,000. The confruntation of these elements with the biological requirements of plants, has led to the drawing up, at the same scale, of ecological maps for the main plants. The study also comprises recommendations for the necessary agro-technical measures, as well as the provisional map of the dirision into districts of the species and races for the main plants and species of animals.

c) In a second stage, the study was deepend and completed at the level of each village of the country, under the leadership of a Central Commission for the division into zones of the agricultural production, with the direct participation of the local agricultural bodies . Numerous new aspects have been concretized and localized in this stage, such as for instance: the quantitative relation between the ecological classes, the size and location of the areas with compulsory use, a.s.o. ,that is the ennumeration of all the resources which enable the adoption of a documented hypothesis of the all-out development of agricultural production.Particular attention has been granted to the study of the agricultural territory of each village and the drawing up of topographical maps at the scale 1:10,000 or 1:20,000 . The location on such territories of the qualitative aspects of the production factors and the calculations made have offered the possibility that in the various stages of synthesis of the study on district ,region or the whole country one could appreciate, in a comparative way, the possibilities of development of the branches and cultures, and establish the most correct proportions.

d) The deepening of the studies regarding the differentiated localizing on territory of the economic and natural conditions has concluded by the drawing up of a hypothesis of development in the future of all the branches of agriculture. At its basis lies the research of social economic and natural conditions under the dependence of which the production process is taking place. The variability of the factors of a geomorphological, climatic and pedological order, associated with the social ,economic factors, reveal from one agricultural enterprise to another, objectively different possibilities of development of the production branches.

e) The division into zones of agricultural production by the final delimitation of ten production zones on the country's territory is used in the drawing up of the measures of economic policy to be taken in view of the increase an intensification of the agricultural output in the Rumanian People's Republic.

The coordinated action of the complex and superior turning to account of the various types of resources

22. No matter how important and varied the inventoried natural resources for the economic development of a country, essential is the industrial activity which turns to account the raw substances obtained from nature, turning the natural resources into manufactured products with an incomparably bigger utility than the objects of labour subjected to processing. This implies a coordination of the action of turning to account the natural resources so that one could ensure a high economic efficiency.

23. In the coordinated action of turning to good account the various types of natural resources, we have to consider the necessity that in all the

the industrial branches and for all the country's natural resources, the technical and economic characteristics of the raw materials must be turned to account, attaining as big values as possible per unit of raw material subjected to processing. The goal is to obtain an as full as possible satisfaction, under the given conditions and for the future, of the necessities of the national economy and the reduction of the expenses of social labour per unit of products - two aspects of the economic efficiency of the turning to account of the natural resources, which are closely connected between them.

24. In Rumania a number of studies are made for ensuring as fully as possible and with small expenses the requirements of the national economy, in choosing the way in which each natural resource is going to be turned to account, the directions and proportions in which they are going to be distributed on branches and products. Based on the system of balance-sheets of the national economy, these studies enable the establishing of : the most adequate proportions in which the various natural resources are going to be exploited and the directions of orientation for their industrial processing, the mutually correlated rate of development of the capacities of extraction and industrial processing for each natural resource; within the processing industry, the rate of development of the production capacities for various stages of industrial processing (sorting, preparation, ennobling, industrial, primary and secondary processing); the most adequate technological methods for the industrial processing of raw materials;the investments that are going to be made for developing the production capacities of industrial processing, first of all of those capacities which through the use of modern technique can make possible the turning out of certain products with a bigger use value; the possibilities resulting from the deepening of relations of international cooperation; the tasks of the scientific researches in the study of new, superior methods of industrial processing, etc.An ample, coordinated action of complex industrial turning to account of the various natural resources is thus achieved on the ensemble of the national economy.

25. a) The achievements obtained by Rumania in the turning to good account of the natural resources in the post-war period,prove the importance of the organization of such a coordinated action of superior turning to account of the soil and subsoil riches. This is also reflected in the changes which occur in the structure of the utilization of the various natural resources, and implicitely on the basis of the raw materials of the different industrial branches.

b) An example is offered in this respect also by the carriers of primary electric power. The policy pursued in this direction has observed the maximum turning to account of the electric power potential of each natural resource; the achievement of an optimum structure of the electric power balance-sheet, as regards, the kinds of power and carriers of primary electric power so that it should ensure the corresponding increase of the electric power basis and of the basis of raw materials necessary to the industry, for a longer period of tine with ever more reduced investments and exploitation expenditure. Thus with the rise of the total production of the carriers of primary electric power, the measures taken for the turning to good account of the considerable reserves of inferior coal made it possible to raise the weight of lignite and brown coal in the balance-sheet of electric power resources, while the measures taken for the rational management and the superior turning to account of wood has led to the systematic and rapid decrease of the weight of fir wood in the production of the carriers of primary electric power (from 14 per cent in 1938 to nearly 4,3 per cent in 1960). The way of using thermo-power resources has also changed during the same process, increasing more rapidly the quantities destined to the turning out of some forms of power and products especially efficient from the point of view of the entire national economy such as : electric power, coke,

semi-coke, the raw materials necessary to the chemical industry. The degree of processing has deepened in the oil processing industry, the structure of production being improved; the weight of benzenes with over 90 octanic number; aromatics have started being produced in our country for the first time (benzene, toluene, xylene, benzene ethyl), fractions for oxasynthesis, hydrofined, chimization gas, etc. In the structure of the utilization of timber, the consumption of wood of inferior use has been reduced (fire wood, charcoal, sleepers) and the consumption for more valuable products has increased (logs for play wood, fibro-wooden slabs and cellulose) also considerably increasing the wooden finite products.

26. The action for a superior turning to account of the natural resources naturally implies, the setting up of industrial units equipped with advanced technique and technology, by the corresponding development of the machine-building industry. At the same time it imposes new forms of organizing industrial production. Rumania's experience proves for instance, the great efficiency of the big works for the complex industrial processing of raw materials concentrated on the use of a single natural resource as basic raw material. In Rumania, such works comprise several production units technologically specialized or specialized on a certain product ensuring the rational, integral and efficient turning to account of the respective raw material. Thus for instance if in a timber yard the basic finite product represented 55-65 per cent of the wood, and in a ply-wood factory 4o-5o per cent of the wood, in the yards for the complex industrialization of wood the finite products amount to 92-99 per cent.

27. The coordinated action of industrial turning to account of the natural resources leads to the continuous increase in the value of the products obtained from the same quantity of raw materials - one of the most important proofs which reflect the results obtained in the use of the natural resources of a country. As a consequence of such an action, in Rumania in the process of socialist industrialization the value of the products obtained from a ton of raw material was in 1960 compared with 1955 nearly 17 per cent bigger at crude oil, 32 per cent at metal, approximately 6o per cent at methane gas, over 66 per cent at wood, which contributed to the more complete satisfaction of the requirements of home consumption and extended the possibilities of the country's participation in international economic exchanges with complex products and of an increased economic value.

28. The coordinated action of superior turning to account of all types of natural resources which a country possess -action based on the scientific inventorying of these resources - on the rational development of extraction - and naturally - of the modern processing industry, as part of which a decisive role is played by the machine-building industry - represents, to our opinion, the main direction towards which the policy of industrialization must be directed, in order to ensure in all countries which are developing, an acceleration of the economic increase, of the rise of national income and the growth of the people's living standard.

1430 E - Nov.1962 - 1,600

E/CONF.39/A/337
5 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.3.1

United States of America

OPPORTUNITIES AND PROBLEMS IN BENEFICIATION AND EXTRACTIVE METALLURGY PRACTICES

By J. Bruce CLEMMER, Research Metallurgist,
J. Howard HEGINBOTHAM, Metallurgical Engineer,
Bureau of Mines,
U.S. Department of the Interior,
Salt Lake City, Utah, and
Washington, D.C.

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

OPPORTUNITIES AND PROBLEMS IN BENEFICIATION AND EXTRACTIVE METALLURGY PRACTICES

by

J. Bruce Clemmer, Research Metallurgist, and J. Howard Heginbotham, Metallurgical Engineer, Bureau of Mines, U.S. Department of the Interior, Salt Lake City, Utah, and Washington, D.C.

Introduction

1. The inseparable relationship of natural resources, their utilization, and industrial development is well known and understood by everyone concerned with national economic studies. The importance of minerals as a natural resource is impressive as shown by world production and consumption statistics. That the supply of mineral resources is diminishing is known by all who produce and utilize mineral raw materials. We mention it now because of the part it has in problems that confront the mineral-dressing and metallurgical professions.

2. The unprecedented industrial growth of recent years has taken a heavy toll of minerals from the more accessible, known deposits. High-grade portions of many ore deposits have been depleted, but, in maintaining a balance between supply and demand, the mining industry has achieved great success in exploiting progressively lower grade deposits of mineral raw materials. To support future industrial growth, new sources of mineral raw materials must be found, and technological progress must be accelerated to keep abreast of the need to utilize resources now considered noncommercial. Accomplishment of both these objectives is a reasonable expectation.

3. Persons who participated in the prodigious task of supplying past mineral raw material requirements pioneered avenues of technical progress that promise help in providing requirements of the future. This is significantly true in the field of minerals beneficiation. In the past 60 years particularly, these men discovered and successfully developed new processes, devices, and machines that greatly advanced mineral dressing technology. Exact scientific knowledge regarding the behavior of minerals under variable treatment conditions was disclosed by patient research during the same period in order to provide a solid foundation for future process developments.

4. This paper briefly reviews the present status of ore beneficiation in the United States with particular reference to processing low-grade, disseminated, and refractory ores. Mention will be made of the important role of chemical extractive metallurgy as applied to ores not amenable to physical treatment by present methods. Remarks on the application of technology to the development and exploitation of mineral deposits in less developed parts of the world will constitute the closing portion of the paper.1/

1/ Selected Bibliography included for reference purposes.

5. With but few exceptions, all minerals produced in the United States, even sand and gravel, currently are subjected to some type of treatment prior to use. The processes involved in beneficiation cover not only minerals in which metals are the principal constituent, but also nonmetallic ores. In a broad sense, beneficiation may mean extracting quantities of mineral from an ore, to obtain a metal or nonmetallic constituent that is only a small percentage of the whole, or, contrariwise, removing small quantities of harmful impurities from an ore comprised almost entirely of the useful mineral. Concentrating copper, lead, and zinc ores by flotation and beneficiating iron ore by magnetic methods are typical examples of the first application. Removing iron oxides from glass sand exemplifies the second application.

6. Mineral-dressing engineers use various physical and chemical characteristics of minerals to obtain a desired separation. Size, shape, and specific gravity; color and luster; electrical conductivity; magnetic susceptibility; hardness and toughness; surface energy; and other inherent or artificially induced properties are utilized to separate the economic minerals from the unwanted gangue materials. Choice of method for beneficiating a specific ore depends primarily on the results of amenability tests in the laboratory.

Handsorting and Cobbing

7. Handsorting and cobbing is the simplest and most direct process for separating broken ore into classes according to grade. As a beneficiation process it serves in several ways, the most important of which are to remove waste rock or high-grade mineral masses from ore before it is ground for subsequent processing and to separate ore constituents into waste and shipping-grade products. The process is especially applicable to ores containing large, easily distinguishable mineral crystals or masses occurring in narrow vein structures that must be mined with much country rock. Disseminated and complex ores that require fine grinding for mineral liberation generally are unsuited to the process.

8. Handsorting and cobbing is not a common practice in the United States because of the scarcity of applicable ores and the high cost of labor. Mechanical cobbing is considered profitable under some circumstances, however, and is still being done in a few cases to upgrade mill feed, for example, at a National Lead operation in upper New York State where titanium and magnetite concentrates are produced. After the ore is crushed, approximately 20 percent of the mined ore is rejected by a cobbing operation that involves conveying a screened intermediate-size (plus 7/16 inch) crusher product over magnetic head pulleys. Pieces containing practically no magnetic material are rejected to waste, and magnetic particles are directed to a third crushing stage ahead of milling operations.

9. Outside the United States, handsorting and cobbing is an extensively used method to upgrade mill feed and to obtain shipping-grade mineral products. Chromite in Pakistan, manganese in Indonesia, antimony in Bolivia, and fluorite in Mexico are but a few of the minerals and countries that offer examples of skillful handcobbing operations. In each operation, a high-grade shipping product is obtained. The rejected material is sorted into two products, a waste product and a middling product that is saved for further processing at some future time.

10. Recovery of mineral in cobbed shipping products is usually below that obtainable by mechanical concentrating methods, but there are compensating advantages to commend the practice, particularly in countries where the cost of labor is not prohibitive. Market specifications for many mineral products, including those mentioned, limit the percentage of contained fine material as determined by screen analysis. Handcobbing minimizes the amount of fines produced, and their percentage in the salable product can thus be effectively controlled. The more obvious advantages of handcobbing are related to operational requirements other than labor; capital investment in equipment is negligible, and the availability of water and power is unimportant. Therefore, if a market for the product exists and if the ore is amenable to beneficiation by handcobbing, small mines can be made productive without first having to develop ore reserves to protect a large capital investment. For what are typically small operations, such as the recovery of feldspar, sheet mica, beryl, and spodumene from zoned pegmatites, handcobbing is more practical than fine grinding and flotation, not withstanding the higher mineral recovery achieved by flotation.

Gravimetric Concentration

11. The concentration of ore fractions, minerals, and metals according to differences in their specific gravity is a process worthy of special distinction; it might be called a process of first and last resort. It is the preferred method for concentrating some minerals and is accepted for the concentration of others only after processes with greater appeal have failed to perform satisfactorily. As a first resort, it is selected for the recovery of gold and valuable minerals found in alluvial deposits and for the concentration of lode minerals such as fluorite and chromite when they can be liberated from their ores at coarse size. Fluorite and chromite are given as examples because market specifications and market preference for metallurgical-grade products generally limit the acceptable amount of contained fines. As a last resort, it is selected as being the best, even though not an entirely satisfactory, method of concentrating minerals, such as cassiterite and scheelite, that are not readily recoverable from lode ores in optimum-grade concentrates. Of course, many other intermediate applications of gravity concentration can be made, either as a preconcentrating step to obtain an enriched product for further treatment or as a single means of producing a finished concentrate when treating simple ores.

12. Jigs, shaking tables, heavy-media separators, and spiral concentrators have retained a position of preeminence among the scores of devices that have been tested as a means of concentrating minerals gravimetrically. Some less known devices designed for specific applications have enjoyed success for short periods but failed to survive in the field of general application. Riffled sluice launders, mechanical bateas, buddles, revolving and stationary convex tables, vanners, kieves and similar devices are outmoded but some are still in use. Currently, fan concentrators are successful in a limited field of application.

13. The dominant position jigs and tables have held for many years is being threatened by heavy-media separators and spiral concentrators. The precise separations obtained by sink-float fractionation over a wide density range when using magnetite or ferrosilicon in aqueous suspension as a parting medium cannot be duplicated by jigging unsized feed coarser than 1/8- or 3/16-inch. High throughput capacity and operating simplicity of cone, drum, or spiral separators

are other attractive features of this method For treating material less than 3/16-inch in size, varying treatment factors will influence a choice between diaphragm-type jigs, spiral concentrators, shaking tables, fan concentrators, and possibly others.

14. Operations that involve the daily treatment of low-value material in large volume tend to favor the use of diaphragm jigs or spirals, particularly as a preconcentrating step. Diaphragm-type jigs are used extensively for this purpose in gold- and tin-dredging operations; spiral concentrators, originally developed to recover chromite from the beach sands of Oregon, now dominate the beach sand industry of Florida for the ultimate recovery of ilmenite. Spirals also appear as scavenger units in numerous mill flowsheets; at a mill in Climax, Colo., they are used to recover wolframite from molybdenum flotation tailings. Their contemplated large-scale use for concentrating specular hematite ores of the Quebec-Labrador district is indicative of a growing trend in iron ore beneficiation practice.

15. For the production by gravimetric methods of high-grade mineral concentrates sold under a penalty-premium-type contract, shaking tables and mineral-type jigs are commonly used for treating material under 1/8-inch size. Hydraulic classification or screen sizing of feed and separate treatment of the resultant fractions is general practice for table concentration of typically amenable minerals, such as those of tungsten, tin, and chrome.

16. Tables and mineral-type jigs are particularly adaptable to small milling operations that can be applied at mines in less developed areas. The role of handcobbing in beneficiating ores from small mines has been described. As a next step toward greater production, gravity methods of concentration can replace handsorting and cobbing, provided either fresh or salt water is available. The capital investment is modest: A small crusher would replace hand breaking of ore, a locally built heavy-media separating vessel would replace handsorting, and if a market exists for fine concentrates, a shaking table would be installed to recover mineral from fine-size material that previously was stockpiled. Crusher and table would be power driven, and all other operations would be performed by hand labor. If handsorting and cobbing was profitable, the proposed scheme of partial mechanization should be more so; as justified by increased ore reserves, further expansion of mechanized mineral-dressing facilities would be a logical next step. This hypothetical example illustrates the possible use of modern gravity concentration techniques in the simplest way. An iron ore beneficiation plant recently built in Liberia includes 384 spiral concentrators and 64 shaking tables in an operation that illustrates large-scale use of similar techniques in what was truly an undeveloped area.

Froth Flotation

17. The froth flotation process, wherein various organic and inorganic chemicals are used to modify the mineral surfaces to enable a separation of particles in an aerated aqueous pulp because of induced difference in their wettability characteristics, has been in the stage of active development for approximately the past 50 years. Even before much was known about the process in terms of precise scientific knowledge, it had literally revolutionized the ore-processing industry. Now it is big business. In 1960, for example, more than 198 million tons of ore were processed by flotation in the United States.

Some 21.5 million tons of 34 different commodities were recovered in concentrates having a market value of approximately $1 billion. Slightly more than 3 billion kilowatts of electrical energy and 222 billion gallons of water were used in 202 operating plants. And the process is still in the stage of development.

18. Enthusiasm over its potential capabilities for the concentration of minerals was first engendered by demonstrations of its ability to separate mineral constituents of ores with specific gravity and particle size characteristics that prevented satisfactory separation by gravimetric methods. Sulfide minerals of copper and zinc (chalcopyrite and sphalerite), each having nominally the same specific gravity, were separated into marketable products; minerals of lead and zinc (galena and sphalerite) were likewise separated by flotation after liberation by grinding their ores to a particle size range below gravity separation capabilities. Those exciting demonstrations and subsequent operational proof of high mineral recoveries, favorable operating costs, and the simplicity and adaptability of flotation to ore changes quickly elevated the process to the predominant position it still holds in the mineral-dressing industry. Exhaustive experimentation has extended its commercial application to a growing list of minerals, and its capabilities and limitations have been generally defined.

19. Flotation is by no means a panacea for all mineral-dressing problems. On the other hand, it cannot be arbitrarily ruled out as a contending process for the beneficiation of a certain ore on the basis of previously unsuccessful attempts to beneficiate similar-type ores. Every ore, regardless of its apparent mineral or physical characteristics, should be tested in the laboratory to investigate its amenability to the process.

20. Less developed nations can profit in many ways from the extensive and costly pioneering by others in the development of the flotation process Knowledge, gained from experience and scientific research, concerning the beneficiation of every mineral used in industry is available to them, generally in published form, either without cost or at nominal cost; well-equipped mineral-dressing laboratories, staffed by competent and experienced engineers, offer their services to test the amenability of ores for a nominal fee; flotation machines, reagent feeders, and complementary types of equipment that have survived competition from literally hundreds of similar machines thoroughly tested in industry are well known because of their outstanding efficiency and durability and are readily available by purchase; a wide variety of flotation reagents has been developed, tested, and standardized to meet broad requirements of the industry; costly patent royalties for the use of process and equipment have been eliminated with possibly a few exceptions; and expert engineering advice is now a common market commodity.

21. The flotation process is applicable to small as well as large beneficiation operations and should be considered in all cases.

Duplex Processes That Involve Flotation

22. Flotation of reground middling products or tailings from shaking tables, flotation of copper sulfides followed by sulfuric acid leaching of flotation tailings to extract oxidized copper for cementation or electrolytic recovery, and flotation and cyanidation of flotation tailings for gold recovery are examples of duplex processes that evolve from routine laboratory amenability

tests. Three old but generally less familiar duplex processes for copper recovery from oxide or mixed sulfide-oxide ores deserve mention because of possible applications in less developed areas. Two of them, leach-precipitation-flotation and segregation-flotation, are typical techniques that link ore beneficiation with extractive metallurgy.

Leach-precipitation-flotation process

23. Industrial application of the leach-precipitation-flotation process (LPF) for handling mixed sulfide-oxide ores dates back to 1929 operations of the Miami Copper Co. in Arizona. It has since been used by the Inspiration Consolidated Copper Co. and Kennecott Copper Co. in Arizona, the Ohio Copper Co. in Utah, the Anaconda Copper Co. in Montana, and possibly others. In the laboratory it has been used successfully for recovering copper from wholly oxidized copper ores. Its principal attribute is that it obviates a solid-liquid separation and is therefore particularly adaptable to treating oxide copper ores that contain a high percentage of slime-producing materials, as well as to treating mixed sulfide-oxide ores.

24. Optional flowsheets have been used successfully for treating ores. In treating old tailings, the Ohio Copper Co., using minus 35-mesh material, first dissolved the oxide copper with sulfuric acid added to agitators; in a second set of agitators, shredded iron was added to precipitate the copper; after precipitation, the pulp went directly to flotation machines that produced a single concentrate of cement and sulfide copper. At Miami, oxide, carbonate, and silicate copper that remained in the sulfide copper flotation tailings was leached with sulfuric acid and precipitated in the pulp with shredded iron. The cement copper was recovered in a high-grade concentrate by flotation.

25. At Kennecott's operation in Arizona, fine-size sponge iron is used for copper precipitation in place of scrap iron. Pyrite from the sulfide flotation plant is utilized for making sulfuric acid for leaching and for producing the sponge iron.

26. Cost and availability of sulfuric acid and scrap or sponge iron requirements are important economic factors when considering the use of this process. The field of application is obviously limited, but when applicable the process has merit; it is easy to control and offers some advantages in regard to plant costs.

The Copper Segregation Process

27. Laboratory discoveries in 1923 led to the development of the segregation process for recovering copper from oxidized and mixed oxide-sulfide ores. Ores that contain calcite or other acid-consuming gangue constituents that make sulfuric acid leaching of the copper impractical may be well suited to treatment by the segregation process. Pilot plant operations in Peru have shown that the process is economic and efficient for recovering both copper and silver from a manganiferous ore that otherwise is difficult to treat. Tests on a semicommercial scale in Arizona also resulted in a satisfactory report on the economics and efficiency of segregating copper from a calcareous and hematitic oxidized ore.

28. Briefly, the process comprises heating the ore to about 700° C in the presence of a small quantity of sodium chloride and a carbonaceous material, such as coal or coke, to produce fine metallic copper which can be recovered by conventional sulfide flotation methods. Although numerous reactions are involved, basically, the copper is volatilized as cuprous chloride and then reduced to the metallic form at the surface of the carbonaceous material.

29. Although the segregation process has been successfully tested on a pilot plant scale several times, further pioneering remains to be done to commercialize the process. It is, however, an attractive method of treating difficult ores and worthy of continued investigation.

Roast-flotation process

30. A number of duplex processes have been developed which involve low-temperature roasting to improve sulfide flotation separations by superficially oxidizing one or more of the mineral species to be rejected. The separations of cobaltite from pyrite and of molybdenite from chalcopyrite are typical. Another interesting application involves low-temperature dehydration of oxide ores, for example, are difficult to float and require abnormal quantities of collector. Dehydration at 400° to 500° C speeds flotation, reduces collector requirements, and improves manganese recovery. Dehydration aids flotation of most hydrous minerals by increasing reactivity of the mineral surfaces.

The Changing Ore Utilization Pattern

31. The minerals industry, in general, is consuming minerals at an increasing rate while simultaneously insisting upon higher grade and better prepared products. The iron ore industry is typical; an abundancy of high-grade and easily minable ore has given way to progressively low-grade material expensive to mine and difficult to beneficiate, as it did with copper, lead, and zinc. Dwindling reserves of direct-shipping ores in the Lake Superior district have forced the companies to turn to washing and gravity concentration of low-grade ores, and more recently to magnetic concentration of taconite and flotation of jaspilite to maintain production. Approximately 70 percent of iron ore shipments made in 1960 was beneficiated ore, compared with only 30 percent in 1950. With the increase in beneficiation and availability of high-grade imported ores, containing 60 percent or more iron, the iron ore consumers were no longer content to accept, without penalty, the traditional direct-shipping grade of 51.5 percent iron. This has proved to be good business. The increase in capacity gained from use of high-grade and better prepared furnace feed, with a commensurate saving in labor, coke, and flux, has greatly improved the overall economics of iron ore utilization.

32. The change in the utilization pattern for iron ores is illustrative of what logically may be expected of other mineral commodities. New and more efficient beneficiation techniques will be necessary to supply the mineral-consuming industries with products tailormade to fit rigid physical and chemical standards.

Role of Chemical Extractive Metallurgy in Ore Utilization

33. The progress made in physical beneficiation has been paralleled by similar improvements in extractive metallurgy. Some of the more significant

recent advances have resulted from the application of chemical processing methods to minerals. Extraction and recovery of uranium, vanadium, rhenium, columbium, zirconium, and the rare-earth elements by ion exchange and solvent extraction, for example, have changed many former concepts about ore processing. New methods have been devised for direct leaching of sulfide ores and concentrates, volatilization techniques have been improved and perfected, new solution purification procedures have been devised, and better and more efficient product recovery methods have been developed. A new discipline of chemical extractive metallurgy has emerged which seems destined to replace some of the older processes and enable practical treatment of still lower grade and more complex ores. Chemical upgrading rapidly is becoming an integral part of the minerals beneficiation field.

Ion Exchange and Solvent Extraction

34. The application of ion exchange and solvent extraction for recovery and purification of uranium from low-grade ores and concentrates was the beginning of a new era in hydrometallurgy. Although the techniques had been used earlier for industrial purposes, including water softening, refining lubricating oils and gasoline, fractionating vegetable oils, and manufacturing pharmaceuticals and antibiotics, the potentialities of ion exchange and solvent extraction in metallurgy were not fully appreciated. The success achieved on uranium gave impetus to broad acceptance of the techniques as useful tools in extractive metallurgy. A partial list of applications includes such diverse separations as uranium from vanadium, molybdenum, iron, and titanium; rhenium from molybdenum; scandium from molybdenum and tungsten; beryllium from iron and aluminum; iron and titanium from aluminum; hafnium from zirconium; cobalt from nickel; tantalum from columbium; thorium from rare-earth elements; and the fractionation of the rare-earth elements.

35. Ability to tailor-make durable and high-capacity synthetic organic resins and liquid ion exchangers from extractions of anionic and cationic constituents gives broad versatility to the technique and suggests increased use in extractive metallurgy as adjunctive processes on low-grade and complex ores. The marked similarity of flotation and ion exchange is apparent; flotation is a physical selector for upgrading ores and ion exchange is a chemical selector for upgrading hydrometallurgical solutions.

36. Ion exchange and solvent extraction processes are expensive, but not unnecessarily so in view of their simplicity and adaptability to separations difficult or impossible by other procedures. An advantage through lower capital or operating costs, better recovery, or higher purity is presupposed to justify their commercial adoption.

Bacterial Metallurgy

37. An interesting recent development in extractive metallurgy is the use of bacteria to promote leaching of copper, manganese, zinc, and molybdenum from low-grade ores. The Thiobacillus thiooxidans, for example, is capable of oxidizing the sulfide in pyrite to form sulfuric acid. Similarly, the Thiobacillus ferrooxidans convert ferrous iron to the ferric state to give an acid-ferric sulfate solution for leaching sulfide and oxidized minerals. Both strains of bacteria are autotrophic and can live on inorganic substances such as dissolved salts, nitrogenous material, carbon dioxide, and oxygen present in

natural water. Improved strains of the bacteria have been developed through cultures that are tolerant to high acid and metal salt concentrations. Work underway at the Bingham mine, Kennecott Copper Corp., has demonstrated that bacterial inoculation speeds materially leaching of oxidized and sulfide copper minerals from the mine waste dumps. Other research has shown that bacterial oxidation accelerates leaching of sphalerite, molybdenite, and various manganese oxides.

Dry Concentration

38. Asbestos and magnetite mineral beneficiation and concentration by dry methods are common procedures. Wet and dry duplex processes are more generally used in the United States for final separation and cleaning of gravity and flotation concentrates to trade specifications. High-intensity magnetic separation to clean glass sand and battery-grade manganese, electrostatic separation of silica from phosphate flotation concentrates, and fractionation of beach sand concentrates by magnetic and electrostatic methods are typical applications.

39. Mineral-bearing sandstones are exceptions to the general rule that low-grade and disseminated ores are not amenable to dry concentration. Dry methods have been used for concentrating certain uraniferous, ferruginous, and copper-bearing sandstones composed of silica grains cemented with the softer uranium, iron, copper and phosphate minerals. Dry attrition grinding and air classification, sometimes supplemented by pneumatic tabling of intermediate middling products from the air classifiers, will often yield satisfactory results in treating ores which do not respond readily to treatment by flotation or other wet processes. Air jigs and pneumatic tables are obtainable from manufacturing firms that specialize in this type of equipment and publish descriptive information and engineering data relative to their operation.

40. Dry concentration is an attractive process for special applications in regions where water is scarce or entirely lacking. One prerequisite to a successful operation is that the material treated must be dry; if fuel is required for removing moisture the additional cost will be an economic disadvantage to dry processing. Other advantages and disadvantages should be investigated and understood before a decision regarding dry processing is made.

Water and Pollution Problems

41. For other than dry methods of ore beneficiation the quantity and quality of water available may limit plant size and govern choice of the flowsheet. The quantity of water required varies considerably for different mills and may range from 10 tons per ton of feed in ore washers and gravity concentrators to approximately 2 tons in sulfide flotation plants. With few exceptions, water recovery is general practice. If the tailings must be impounded to avoid difficulty arising from pollution of water used elsewhere for agricultural or municipal purposes, part of the tailing pond water may be recycled if economically advantageous. The unretrievable water lost by evaporation from the tailings pond is serious only in arid regions, and loss from seepage can be minimized by sealing porous strata with slime or clay. With reasonable care, recovery of up to 70 percent of the process water for return to the mill circuit generally is possible. The recovered water seldom is crystal clear, but the solids content can be controlled within reasonable limits by flocculation of the slimes with lime, starch, glue, various natural gums, and synthetic organic flocculents, such as the polyacrylamides, which are widely used for solid-liquid separation in the mining and metallurgical industries.

42. The permissible quantity of water that can be recycled is greatest for gravity circuits and least for flotation because of buildup of soluble salts and unconsumed reagents which destroy selectivity and reduce recovery. The tolerance toward contaminated water is least in fatty acid flotation of nonmetallics and greatest in bulk flotation of sulfide ores. Selective flotation processes are sensitive to changes in composition of the recycled water, and frequent reagent adjustment may be necessary to maintain selectivity. Water treatment is expensive but may be necessary if an adequate supply of good-quality water is not available for the flotation circuit.

Exploitation of Mineral Resources in Less Developed Areas

43. A hypothetical example of using handsorting and gravity concentration methods to help develop a prospective mine has been given previously. By American tradition, this is referred to as a "bootstrap" or "make pay as you go" approach. Many mineral prospects have been developed into highly profitable commercial operations by little more than man's ingenuity, perseverence, and hard work. In many instances, beneficiation of the ore was necessary and usable methods were limited to handsorting or simple gravity concentration with rockers, sluiceboxes, or shaking tables until the prospect was developed into a mine and a more elaborate treatment plant was justified. Mention of this simple approach does not imply that less developed areas need revert to primitive methods to start developing their mineral resources, although such methods should not be overlooked. Rather, it suggests that a careful study be made to delineate the scope and nature of the specific mineral problems of the particular area and that a choice then be made of those segments of advanced technology that can be applied or modified to meet the particular problems involved.

44. The problem of beneficiating ore in remote areas, for example, has been greatly simplified by the development of mobile and portable beneficiation plants of different sizes. The plants are unitized, and the individual pieces of machinery have been designed for transportation by primitive means. Complete plants are available for crushing, screening, and grinding, alone or in conjunction with different types of gravity, amalgamation, cyanidation, magnetic, and flotation unit operations. Diesel and gasoline powerplants of unitized construction also are available. In the less developed areas, such plants will have unique advantages as pilot mills that can be expanded into permanent plants or dismantled and moved to test other more favorable deposits.

45. Another kind of plant that merits consideration for less developed areas is the custom mill, a mill designed and built to process ores from several mines located generally in the same district. The operators of such mills may either purchase ore outright on the basis of its assay value or process the ore for a flat fee per ton and either return the products to the owner or arrange for their sale under a cooperative marketing plan. Such mills have operated successfully in the United States and other countries. In Peru, at least five custom mills have been built and operated by a Government agency in widely separated districts to process ore from several mines and indirectly to provide a market for the ore without which the mines would have remained idle. For such mills to be successful there must be some certainty that sufficient ore is available for treatment in the district to pay out the cost of the plant and to keep it operating on a scale that will be profitable for plant operator and miner alike.

46. The lack of skilled labor and technicians has been cited as a deterrent to mineral development in certain areas. The problem is real but perhaps overemphasized. People learn rapidly by imitation and can be easily trained to operate a jackhammer, a jig, or a flotation machine. It is essential, however, that a nucleus of highly trained and proficient engineers of all disciplines be available to plan and direct the mineral development programs.

47. This points to the need for better dissemination of technical information on a worldwide basis and formal mineral-dressing education for those who will be responsible for adapting mineral-dressing techniques to the beneficiation of minerals in less developed areas. It should be added here that other needs exist, principally for laboratory facilities having basic equipment units for testing the amenability of ores to beneficiation by methods in general use and for facilities for fire assaying and chemical analyses of ores.

Dissemination of Technical Information

48. Scientific and engineering progress in mineral dressing and extractive metallurgy has been faithfully recorded from infancy to its present state of maturity in technical periodicals, published proceedings of professional organizations, textbooks, and other publications, including those of Government agencies.

49. Most of this information is preserved in technical libraries located primarily in the industrialized nations. In many new nations documentation facilities are not available for general use and frequently the professional ore dresser is obligated to work without adequate knowledge of what is going on or what has gone on in the rest of the world. A central source of published information on old as well as new process techniques and practices that is equipped to function on a worldwide basis is an obvious need. It should include among its facilities an automated information retrieval system, a duplication service, and unlimited translation capabilities. It should serve particularly the needs of less developed nations. International group action, by providing this service, can make an outstanding contribution to the technical advancement of new nations.

Mineral-Dressing Laboratory Facilities

50. It has been suggested that laboratory facilities are needed in less developed areas. In order of priority this need follows that of education. To equip such laboratories is relatively simple, so simple in fact that a great many have been established throughout the world and have since remained idle for lack of a technical staff to direct their use. To staff a laboratory with capable technologists is not a simple matter and this problem should be resolved before commitments for physical facilities are made. In establishing a mineral-dressing laboratory a modest approach is the best approach. Its planned purpose should be limited to the testing of ores for their amenability to beneficiation by the better known and more widely used methods of mineral dressing, and if this is done the requisite equipment, apparatus, and supplies will be kept to a minimum. An analytical section will be an essential adjunct to the mineral-dressing laboratory.

51. Without modifications and imaginative applications corresponding to actual needs, the potential benefit of advanced mineral-dressing methods to less developed nations cannot be fully realized.

Selected Bibliography

1. Bean, J. J., LPF at Miami, Analysis of Latest Operations, Mining Engineering, Volume 12, December 1960, pages 1265-70.

2. Franz, M. W., Leach-Precipitation-Flotation Process, Journal of Metals, Volume 11, June 1959, pages 382-385.

3. Freeman, G. A., C. Rampacek, and L. G. Evans, Copper Segregation at the Lake Shore Mine, Journal of Metals, Volume 13, May 1961, pages 370-372.

4. Gaudin, A. M. Flotation, McGraw-Hill Book Company, Inc., New York, 1932.

5. Malouff, E. E. and J. D. Prater, Role of Bacteria in the Alteration of Sulfide Minerals, Journal of Metals, Volume 13, May 1961, pages 353-356.

6. Perkins, E. C. and F. Novielli, Bacterial Leaching of Manganese Ores, Mining Congress Journal, Volume 44, August 1958, pages 72-73.

7. Rampacek, C., W. A. McKinney, and P. T. Waddleton, Treatment of Oxidized and Mixed Oxide-Sulfide Copper Ores by the Segregation Process, Bureau of Mines Report of Investigations 5501, 1959, 28 pages.

8. Rose, E. H., Iron Ore: The Big Picture, Mining Engineering, Volume 13, September 1961, pages 1052-1058.

9. Staff, Nonferrous Ore Dressing in the U.S.A. Report of the Technical Assistance Mission No. 54, The Organization for European Economic Cooperation, Paris, 1953.

10. Sutton, J. A. and J. D. Corrick, Bacteria in Mining and Metallurgy: Leaching Selected Ores and Minerals; Experiments with Thiobacillus Thiooxidans, Bureau of Mines Report of Investigations 5839, 1961, 16 pages.

11. Taggart, A. W., Handbook of Ore Dressing, John Wiley & Sons, Inc., New York, 1945.

12. Zimmerley, S. R. and S. F. Ravitz, Pilot-Plant Investigation of Concentration of Blackbird Cobalt Ore by Roast-Flotation Process, Transactions American Institute of Mining, Metallurgical and Petroleum Engineers, Volume 187, 1950, pages 1044-1046.

13. Zimmerley, S. R., D. G. Wilson, and J. D. Prater, Cyclic Leaching Process Employing Iron Oxidizing Bacteria, U.S. Patent 2,829,964, August 8, 1958.

1656 E - Nov.1962 - 1.600

ПРИМЕЧАНИЯ

1. Документы, включенные в число материалов, принятых для обсуждения на общих сессиях, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

2. Документы, включенные в число материалов, принятых для обсуждения на специализированных сессиях, будут в распоряжении делегатов Конференции только на одном из этих официальных языков.

3. Резюме всех документов в том виде, в каком они были представлены их составителями, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

4. До открытия Конференции документы и резюме не будут выпущены для общего распространения. Они будут опубликованы заблаговременно только в ограниченном числе экземпляров и исключительно для правительственных делегаций и других правомочных участников. Последующие опубликование и рассылка трудов Конференции будут обеспечены в соответствии с практикой Организации Объединенных Наций, как это установлено ее Издательским комитетом.

ЭФФЕКТИВНЫЕ МЕТОДЫ ОТКРЫТИЯ НОВЫХ МЕСТОРОЖДЕНИЙ НЕФТИ И ГАЗА В МЕНЕЕ ИССЛЕДОВАННЫХ ТЕРРИТОРИЯХ

Г.Л.Дикенштейн, доктор геолого-минералогических наук,
М.К.Калинко, доктор геолого-минералогических наук,
С.П.Максимов, кандидат геолого-минералогических наук и
Д.С.Халтурин, кандидат геолого-минералогических наук,
научные сотрудники Всесоюзного научно-исследовательского геологоразведочного нефтяного института

В Советском Союзе разработан рациональный комплекс методов геолого-геофизических и геологоразведочных работ, применение которого позволяет весьма эффективно и быстро открывать новые месторождения нефти и газа в менее исследованных и обычно труднодоступных районах. Так, например, в последние 8 лет открыты месторождения нефти и газа в Западной и Восточной Сибири /Мегионское, Шаимское, Марковское, Тас-Тумусское и др./, в Казахстане /Жетыбайское, Узеньское, Прорвинское и др./, в Узбекистане /Газлинское, Мубарекское и др./ и Туркменистане /Дарваза-Зеаглинское, Байрамалинское и др./. Этот метод заключается в последовательном проведении определенных видов геологических, геофизических и разведочных работ, сопровождаемых детальными исследованиями и обобщением получаемых данных и охватывающих территорию всего нефтегазоносного бассейна в целом.

Содержание работ на каждом этапе и их общая стоимость могут быть самыми различными и зависят от размера территории, характера геологического строения и степени изученности. В отдельных случаях возможно совмещение или уменьшение количества этапов, что может обеспечить открытие месторождений в начальные этапы работ.

В общем случае первым этапом является выявление на основании общегеологических данных возможно нефтегазоносных бассейнов. При современной стадии геологической изученности мира, подобные бассейны могут быть выявлены почти на всех континентах и островах, за исключением быть может, Антарктиды и Гренландии. Для того, чтобы в выявленных бассейнах определить направление поисковых работ, проводят маршрутные геологические исследования. Затраты на проведение этих исследований обычно незначительны, так как требуется работа единичных полевых геологических партий, количество которых зависит от размера территории.

Затем обобщают все имеющиеся данные, пользуясь проведенными во время маршрутных исследований наблюдениями и составляют план региональных исследований для всего бассейна в целом, перед которыми ставят следующие задачи:

а/ выявление особенностей строения осадочной толщи и стратиграфического расчленения;

б/ выявление условий осадконакопления, выделение фаций и основных закономерностей их распространения, а также распределения мощностей отдельных стратиграфических комплексов, свит, горизонтов и пластов;

в/ выявление геоструктурной и палеоструктурной обстановки: выделение крупных структурных элементов как по поверхности фундамента, так и внутри осадочной толщи и выяснение основных закономерностей истории их развития;

г/ выделение зон нефтегазонакопления;

д/ выяснение наличия коллекторов и газо-нефте-водонепроницаемых перекрытий, их положения в разрезе и распространения по площади;

е/ сравнительная оценка степени перспективности отдельных участков территории с выделением площадей для проведения более детальных работ.

Этот комплекс региональных исследований различен для районов с различным геологическим строением. В целом же он складывается из следующих видов исследований:

1. Геологическая и аэрогеологическая съемки 1:500000 - 1:100000.

2. Аэромагнитная съемка 1:500000 и крупнее.

3. Геоморфологические /морфометрические/ исследования.

4. Гравиметровая съемка с сечением изоаномал через 1 - 2 миллигал.

5. Комплекс сейсмических исследований: профили КМПВ, ОВ, ГСЗ.

6. Профильное бурение.

7. Опорное бурение.

8. Всестороннее геолого-геофизическое и геохимическое изучение разреза пород, слагающих район.

По результатам перечисленных видов исследований производится научное обобщение материалов и составляется серия геологических и геофизических карт с результирующей картой прогнозов нефтегазоносности, позволяющей наметить конкретные объекты для детальных поисковых работ.

Применение аэрометодов особенно эффективно при выяснении общих черт геологического строения крупных территорий Аэрогеологическая съемка с наземным дешифрированием полностью себя оправдала в районах Кавказа, Средней Азии и Сибири.

Аэромагнитная съемка в комплексе с наземной гравиметровой является необходимой основой для составления предварительного представления о глубинном строении исследуемой территории.

Применяется комплекс сейсмических исследований и глубокого бурения по системам региональных профилей. Расстояния между региональными профилями и скважинами на них определяются конкретной геологической обстановкой.

Особо важное значение имеет разработанный и применяемый только в СССР метод опорного бурения, заключающийся в проведении специальных глубоких скважин, в задачу которых входит выяснение разреза, закономерностей его изменения в пространстве и возможной нефтегазоносности отдельных стратиграфических комплексов.

Места заложения опорных скважин определяются на основании комплекса геолого-геофизических данных. Довольно часто при помощи опорных скважин удается открыть месторождения нефти и газа в новых провинциях /Березовское, Марковское и др./.

Материалы указанных работ параллельно обрабатываются отдельными тематическими партиями, благодаря чему одновременно проводится обобщение всех данных с целью выявления наиболее перспективных территорий для открытия крупных месторождения нефти и газа.

Проведение перечисленного выше комплекса региональных работ одновременно на всей территории позволяет в сравнительно короткий срок определить перспективы ее нефтегазоносности. Так, например, проведение в течение 5 лет региональных исследований на территории Западной Сибири позволило не только определить перспективы этой провинции, занимающей огромную площадь /свыше 4 000 000км²/ и являющейся исключительно труднодоступной и представляющей сплошную тайгу и болота, но и открыть в ней 14 месторождений нефти и газа.

Перечисленный выше полный комплекс исследований рассчитан на изучение крупных возможно нефтегазоносных территорий, площади которых измеряются многими сотнями тысяч квадратных километров и закрытых новейшими отложениями. В возможно нефтегазоносных бассейнах меньшего размера, или отличающихся обнаженностью коренных пород, многие из перечисленных выше задач могут быть решены при геологических исследованиях, на основании изучения пород в естественных обнажениях как внутри бассейна, так и в смежных территориях. Благодаря этому, в таких случаях можно непосредственно после маршрутных исследований проводить на выявленных перспективных площадях геологическую съемку, в задачу которой должна входить подготовка площади к глубокому поисковому бурению. Подобная методика требует небольших затрат на проведение подготовительных работ - они состоят, в основном, из стоимости содержания 1-2 геологических партий. Тщательные геологические исследования с соблюдением всех требований, предъявляемых разработанной в СССР инструкции для геологического картирования, позволяют достаточно уверенно наметить места для бурения первых поисковых скважин, большинство которых в таких случаях оказывается успешным и приводят к открытию месторождений нефти и газа.

Проведение работ по этой методике в обнаженных районах и сравнительно небольших по территории бассейнах обеспечивает открытие месторождений нефти и газа при минимальных затратах средств и в короткие сроки.

Данные, полученные в результате проведения региональных исследований, позволяют не только открыть месторождения нефти и газа, но и определить те районы, в которых возможно открытие крупных месторождений. Так, например, при проведении региональных работ в Туркмении и Узбекистане удалось в короткий срок не только выяснить перспективы нефтегазоносности огромной /свыше 1 000 000 км^2/ и труднодоступной территории, занятой пустынями Кара-Кум и Кызыл-Кум, и открыть здесь месторождения нефти и газа, но и направить поисковые работы на разведку таких наиболее крупных месторождений как Газлинское и Дарваза-Зеаглинское.

В Волго-Уральской области путем проведения профильного бурения с расстоянием между скважинами до 15 км было открыто богатейшее нефтяное месторождение - Ромашкинское.

Выявленные при региональных работах площади, на которых возможно наличие крупных месторождений нефти и газа, подготавливаются затем к проведению поискового бурения.

Основным методом подготовки площадей к поисковому бурению является детальная сейсморазведка методом МОВ или разработанным в СССР методом РНП и бурение параметрических скважин малого диаметра.

Показателями подготовленности площади к постановке глубокого поискового бурения являются:

а/ наличие в разрезе осадочной толщи свит, горизонтов или пластов, перспективных в отношении нефтегазоносности, промышленная оценка которых получена в данном районе или в данной структурно-фациальной зоне;

б/ сведения об общей форме структуры, блока и пр., наличие достоверных сведений о глубинном строении площади на различных стратиграфических уровнях, доказывающих соотношение структурных планов различных горизонтов;

в/ возможность предварительной оценки перспективных запасов нефти или газа.

Исключительно большое значение для эффективных поисков месторождений имеет рациональное размещение первых глубоких скважин. Наиболее целесообразно применение профильной системы, которая пригодна для любого типа структур. Система скважин, расположенных по профилям, обеспечивает наибольшую эффективность с точки зрения получения геологических результатов. Профили закладываются вкрест простирания структуры, причем расстояния между скважинами определяются длиной короткой оси и углами падения пород на крыльях.

В общем виде одна из первых трех скважин должна вскрыть залежь в сводовой части, вторая - на пологом крыле, третья - по расчетным данным - вблизи водонефтяного /или газо-водяного контакта. Такая методика заложения первых скважин позволяет избежать бурения лишних скважин и ускоряет процесс открытия месторождений.

Особое внимание уделяется опробованию разведочных скважин. При вскрытии слабопроницаемых горизонтов или горизонтов, сложенных коллекторами трещинного типа, принимаются меры для обеспечения сообщаемости пласта со скважиной. В первом случае эффективно применение специальных поверхностно-активных веществ и нередко гидроразрывов, во втором - гидрокислотных разрывов с закреплением образующихся трещин специальным материалом, предохраняющим их от закрытия.

Одновременное бурение двух-трех скважин через свод структуры при наличии детальной сейсмической карты, как правило, позволяет сразу определить масштабы открытого месторождения. Так например, на Газлинском газовом месторождении после бурения первых четырех скважин стало ясно, что на данной площади имеется уникальная по своим размерам залежь.

В Советском Союзе разработан метод при помощи которого даже по первой скважине, вскрывшей газовую залежь, можно определить примерные ее запасы. Принцип этого метода заключается в том, что из залежи точно замеряемое количество газа по скважине перепускается в один из вышележащих водоносных горизонтов /лучше нефтеносных, если таковые имеются/ или газопровод. По разности пластовых давлений до перепуска и после него, зная количество газа, выпущенного из залежи, легко подсчитать объем последней. Во всех разведочных скважинах продуктивные горизонты вскрываются с отбором керна, детальные исследования которого позволяют определить коллекторские свойства пород и степень их нефте и газонасыщенности. Если характер нефти и газа, насыщающих пласты, не удается установить достаточно достоверно /вследствие малого выноса керна, наличия неконсолидированных осадков и т.д./, то отбирается проба флюидов и породы с помощью специального пробоотборника.

Ориентировочные запасы углеводородов в открытом месторождении могут быть определены путем применения методов разработанной в СССР гидродинамической разведки, заключающейся в детальном исследовании динамики пластовых давлений. Применение этих методов не требует бурения специальных скважин и поэтому не вызывает значительных затрат средств.

При вскрытии горизонтов, сложенных коллекторами трещинно-кавернозного типа, изучение их проводится специальным комплексом геофизических методов, а также микро-петрографическим методом. Применяя эти методы, определяют емкость и проницаемость коллекторов трещинно-кавернозного типа, вскрытых буровыми скважинами.

После открытия залежи проводится разведочное бурение, в задачу которого входят определение геометрической формы залежей, запасов заключенных в ней углеводородов, режима ее и характера резервуара. При разведке всей залежи в целом, а не отдельных ее участков, можно указанные задачи решить минимальным числом разведочных скважин, закладывая их таким образом, чтобы осветили все особенности залежи на всей площади ее распространения. Так, например, на упомянутом выше Газлинском месторождении, путем бурения всего лишь 9 разведочных скважин с суммарным метражем 12.228 м можно было разведать запасы газа объемом 438 млрд. м^3, на площади свыше 21.000 га.

Обобщение данных по всем разведочным скважинам позволяет определить как общую емкость продуктивного горизонта и количество заключенных в них жидких и газообразных углеводородов, так и закономерности изменения свойств пород по площади. Благодаря этому к началу разработки имеются основные данные, необходимые для электрического моделирования пласта. На такой модели при помощи электронно-счетной машины решается задача рациональной разработки, составляя проект которой преследуют цель при минимальных капиталовложениях получить необходимый уровень добычи нефти и /или/ газа, достигая при этом максимально возможной нефтеотдачи. Проведенные на многочисленных моделях теоретические расчеты и экспериментальные исследования на различных месторождениях /Бавлинском и др./ показывают, что на нефтяных месторождениях указанные цели лучше всего достигаются при проведении редкой последовательно сгущающейся сетки эксплуатационных скважин. При этом, конечно, разработка с самого начала ведется с поддержанием пластового давления, что осуществляется путем законтурного заводнения или нагнетания газа.

При разработке крупных нефтяных залежей весьма эффективным оказывается применение внутриконтурного заводнения, при котором вся залежь искусственно расчленяется на ряд отдельных залежей, разрабатываемых самостоятельно. Это позволяет при необходимости добычи большого количества нефти вести интенсивную разработку, не снижая коэффициента нефтеотдачи.

Началу разработки предшествует проведение технико-экономических исследований, имеющих целью выяснение наиболее эффективного использования добываемых нефти и газа. Определяются и строятся необходимые нефте- и газопроводы, железные и шоссейные дороги, а также жилые помещения для обслуживающего персонала. Так, например, основным потребителем газа, который будет добываться на Газлинском месторождении, определена промышленность Урала. Поэтому до начала разработки указанного месторождения строится газопровод Газли-Свердловск.

Одновременно с началом разработки Ромашкинского нефтяного месторождения проводилось строительство городов для нефтяников Альметьевска и Ленинска. Таким образом, применяя описанный выше комплекс исследований, можно за сравнительно короткий промежуток времени при сравнительно небольших затратах средств выяснить основные черты геологического строения площади, определить перспективы ее нефтегазоносности и выбрать и подготовить к разработке наиболее богатые месторождения нефти и газа.

1624 R - Nov.1962 - 600

E/CONF.39/A/339
5 Nov.1962
ORIGINAL : RUSSIAN

КОНФЕРЕНЦИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ
ПО ВОПРОСУ О ПРИМЕНЕНИИ НАУЧНЫХ И ТЕХНИЧЕСКИХ ЗНАНИЙ
ДЛЯ УДОВЛЕТВОРЕНИЯ ПОТРЕБНОСТЕЙ МЕНЕЕ РАЗВИТЫХ РАЙОНОВ

ПУНКТ ПОВЕСТКИ ДНЯ: A.5.2.1

УКРАИНСКАЯ ССР

МИНЕРАЛЬНЫЕ РЕСУРСЫ ПРИБРЕЖНЫХ МОРСКИХ ВОД И ПЛЯЖЕВЫХ ЗОН

Составил В. П. ЗЕНКОВИЧ,
Доктор наук,
Институт океанографии
Академии наук СССР

Документы, составленные для Конференции Организации Объединенных Наций по вопросу о применении научных и технических знаний для удовлетворения потребностей менее развитых районов, служат в качестве рабочих документов для этой Конференции. Они опубликованы в том виде, в каком были представлены их составителями, и их содержимое и выраженные в них мнения принадлежат их составителям (см. примечания на оборотной стороне).

ПРИМЕЧАНИЯ

1. Документы, включенные в число материалов, принятых для обсуждения на общих сессиях, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

2. Документы, включенные в число материалов, принятых для обсуждения на специализированных сессиях, будут в распоряжении делегатов Конференции только на одном из этих официальных языков.

3. Резюме всех документов в том виде, в каком они были представлены их составителями, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

4. До открытия Конференции документы и резюме не будут выпущены для общего распространения. Они будут опубликованы заблаговременно только в ограниченном числе экземпляров и исключительно для правительственных делегаций и других правомочных участников. Последующие опубликование и рассылка трудов Конференции будут обеспечены в соответствии с практикой Организации Объединенных Наций, как это установлено ее Издательским комитетом.

МИНЕРАЛЬНЫЕ РЕСУРСЫ ПРИБРЕЖНЫХ МОРСКИХ ВОД И ПЛЯЖЕВЫХ ЗОН.

Доктор наук ЗЕНКОВИЧ В.П.
Институт океанографии Академии наук СССР.

Некоторые ценные металлы / олово, титан, германий, частично уран и др./ редко встречаются в виде руд, а образуют преимущественно россыпные месторождения соответствующих минералов / касситерит, титанит и др./. Иногда ценные металлы образуют лишь незначительную примесь или составную часть сложных минералов /монацит, магнетит, циркон и многие другие/. Экономическое значение многих редких металлов стало сейчас исключительно важным.

Россыпные месторождения формируются в руслах рек, а в ещё больших количествах - на морских берегах. Эксплуатируются не только современные месторождения, но и древние, которые давно потеряли связь с образовавшим их фактором - движущейся водой, но имеют генезис аналогичный современным.

Все минералы, содержащие ценные металлы, имеют высокий удельный вес /> 2,8/ и движущаяся вода отделяет их от основной массы наносов /кварц, полевые шпаты и др./ в виде концентратов с большим содержанием /десятки %%/ ценного продукта. В море сепарирующим агентом являются волны, действие которых во время сильного шторма распространяется на глубину до 50 м /на берегу открытого океана/. Ценные минералы накапливаются в составе песков и алевритов. Размер их зерен колеблется в пределах 0.05-0.5 мм. Образованию мощных концентратов способствует тропический и субтропический климат, при котором происходит интенсивное выветривание коренных горных пород.

В настоящее время широко эксплуатируются пляжевые россыпные месторождения на берегах Индии, Индонезии, Австралии, Японии, КНР и др. По-видимому, перспективными являются береговые отложения Африканского и Южно-Американского континентов. Известно, что в береговых россыпях в небольших количествах разрабатываются алмазы /Зап. берег Африки/ и урановое сырьё / Вост.берег Южной Америки/. В некоторых странах /Япония, Италия/ оказывается экономически целесообразным вести разработки береговых россыпей даже такого дешевого продукта, как железо / в виде магнетита/.

Необходимо подчеркнуть, что россыпные месторождения приурочены не только к современной пляжевой полосе, но встречаются и на небольших глубинах морского дна /напр.подводные россыпи касситерита в Индонезии/, а также на древних морских террасах на высоте во много десятков метров над морем. Известны кроме того месторождения в прибрежных дюнах / напр.Зап.берег Австралии/. Таким образом, морское побережье представляет собой довольно широкую область, перспективную на указанные выше полезные минералы.

За последнее время выявлены важные закономерности, на основании которых можно надеяться усилить эксплуатацию уже существующих месторождений, а также открыть новые. В обоих случаях это сулит положительный экономический эффект для народного хозяйства слабо

развитых стран, преимущественно тропической и субтропической зон.

Установлено, что запасы концентратов на пляже возобновляются после штормового зимнего сезона. Это позволяет вести многолетние повторные разработки ценного сырья в одном и том же месте.

В одних случаях / напр.на восточном побережьи Индии/ процесс возобновления связан с тем, что реки, устья которых расположены на данном побережьи, ежегодно вносят в море новые массы аллювия, содержащего ценные минералы. Этот аллювий оседает на дно в пределах морских мелководий, а затем перемещается волнами и частично выбрасывается на пляж. В этом проявляется сепарирующая роль морского волнения, которое способствует выбрасыванию на берег в первую очередь именно тяжелых минеральных частиц / наибольшей гидравлической крупности, а при одинаковой абсолютной крупности - наибольшего удельного веса/.

Однако, во многих случаях возобновление пляжевых запасов не связано с деятельностью современных рек /Азовское и сев.-зап.часть Черного морей, Беринговo море и др./. В условиях, когда современный песчаный и алевритовый аллювий в море не поступает, резервом минерального сырья может быть только морское дно - то есть его новейшие голоценовые отложения.

В связи с этим, большой интерес имеют новейшие советские исследования толщ прибрежных отложений, выполненные с помощью вибро-поршневой трубки / vibro-piston core-sampler /. Этот прибор позволяет получать с небольшого судна ненарушенные колонки не только тонких, но и грубозернистых отложений, каковы пески, гравий, ракушка и даже галька. Длина колонок у существующей рабочей модели прибора составляет 5 м. /проектируется модель с колонкой до 10 м/. Глубина работы прибора - до 100 м. Им можно работать также на суше, пользуясь грузовой автомашиной для транспорта.

Работы, выполненные Институтом океанологии Академии наук СССР на морях: Черном, Азовском, Балтийском, Японском и Охотском показали, что почти повсеместно на глубинах до 30-40 м сохранились реликтовые береговые формы. Они были созданы в период поздне-ледниковой /голоценовой/ трансгрессии мирового океана.

Эти формы представляют собой валообразные песчаные тела, вытянутые вдоль ровных морских берегов, или перегораживающие поперек крупные заливы. Древние береговые формы обычно состоят из относительно крупного песка с примесью ракуши, гравия и гальки.

Анализы материала, собранного на Черном море, показали, что пески древних прибрежных образований часто бывают обогащены тяжелыми минералами, хотя и не в таком количестве, какое встречается в тонких прослоях концентратов на современных пляжах. В последних количество тяжелых минералов достигает 90% и даже более, но масса этого материала очень невелика. На участках наших исследований на Черном море среднее содержание тяжелых минералов на современных пляжах составляет до 3-4%./ При наличии очагов более высоких концентраций, пригодных для экономического использования/. Пески подводного берегового склона содержат менее 1% тяжелых минералов. В линзах древних береговых образований на морском дне среднее содержание тяжелых минералов повышается до 2% и несколько более.

Однако нужно заметить, что объем материала каждого из древних береговых оразований на морском дне во много раз /иногда до 10/ превышает объем современных пляжей /без дюн там, где они имеются/. Второе важное обстоятельство заключается в том, что пески с морского дна технически проще эксплуатировать, чем с пляжей. В последнем случае требуется организация карьеров и автотранспорта, что удорожает получаемый продукт. Донные же пески можно рефулиро-

вать на баржи, что стоит дешевле и делается несравненно быстрее.

Совокупность имеющихся данных показывает, что в период голоценового низкого положения уровня океана и связанных с ним морей, вдоль большинства современных берегов располагалась полоса аккумулятивной равнины, питавшейся преимущественно аллювиальным материалом. В период затопления этой равнины водами моря, происходила селекция её материала по гидравлической крупности. Этот материал мог микрировать на большие расстояния вдоль берегов, а одновременно перемещался в сторону суши. В результате, часть песков пошла на создание современных пляжей, но основная масса осталась на морском дне в виде удлиненных песчаных тел /аналогов барьерных островов/ или в виде разобщенного тонкого покрова, ныне захороненного под слоем илистых отложений. Эта закономерность, очевидно, имеет планетарный характер.

Из указанных донных очагов продолжает происходить частичное питание современных пляжей. Во многих местах реликтовые береговые формы сохраняют большой запас ценных тяжелых минералов, которые могут быть разведаны и поступить в эксплуатацию. Благодаря тому, что пески ещё при низких уровнях моря были перемещены на большие расстояния /иногда сотни километров/, современные очаги тяжелых минералов на дне и на пляже могут быть оторваны от источников современного питания и располагаться изолированно. Это затрудняет их поиски обычными геологическими методами.

Из сказанного следует, что при изучении природных ресурсов слабо развитых стран, необходима организация исследований прибрежной зоны моря. Кроме выявления потенциальных запасов минерального сырья, эти исследования имеют большое значение так же для гидротехники /строительство портов и борьба с их заносимостью, строительство дамб для получения новых земель, используемых в сельском хозяйстве, и мелиорация этих земель и пр./.

При организации указанных работ в первую очередь должны быть предусмотрены рекогносцировочные наземные геоморфолого-геологические обследования. Они позволяют выявить наиболее перспективные участки на минеральное сырьё. После этого организуются морские разведочные работы с вибропоршневой трубкой и водолазным обследованием морского дна с помощью аквалангов. Морские работы производятся с небольшого корабля /100-200 регистровых брутто-тонн/, имеющего грузоподъемную стрелу и лебедку мощностью 1 1/2 - 2 тонны. За один год исследовательская партия в составе 5 человек может собрать материал, характеризующий строение дна и берега и перспективы использования тяжелых минералов на протяжении примерно 500 км. полосы берега.

Кроме своего непосредственного экономического эффекта, указанные исследования целесообразны еще и потому, что только на их основании можно выявить надежные поисковые признаки для разведки месторождений тяжелых минералов в отложениях древних морей тех же геологических провинций. Эти отложения погребены под покровом более молодых и редко бывают сами по себе доступны для непосредственного геологического исследования.

Доктор наук Зенкович В.П.

Институт океанологии АН СССР, Москва

Литература

Зенкович В.П. Основные проблемы Геоморфологии морских берегов. Мат.2-го Совещ.Геоморфологической комиссии АН СССР,Москва,1959.

Зенкович В.П. Основы учения о развитии морских берегов АН СССР, Москва,1962.

Зенкович В.П. Леонтьев В.П.,Невесский Е.Н. Влияние эвстатической послеледниковой трансгрессии на развитие прибрежной зоны морей СССР. XXI Межд.Геолог.Конгресс. Изд-во АН СССР,1960.

Медведев В.С. Долотов Ю.С.,Щербаков Ф.А. Некоторые черты строения и развития берегов южного Приморья. Тр.Института океанологии АН СССР,т.48,1961.

Невесский Е.Н. Исследование толщ прибрежных отложений с помощью вибропоршневой трубки. Докл.АН СССР.т.112, № 3, 1957.

Невесский Е.Н. Изучение истории развития Анапской пересыпи на основе анализа толщ прибрежных и береговых осадков. Тр.Ин-та океанологии АН СССР,т.28.1956.

Невесский Е.Н. Некоторые данные о послеледниковой эволюции Каркинитского залива. Тр.Ин-та океанологии,т.48,1961.

Невесский Е.Н. Невесская Л.А. К вопросу о строении и истории формирования толщ прибрежных морских отложений в голоцене. Тр.Ин-та Геологии АН Эстонской ССР,т.8, 1961.

Павлидис Ю.А. Некоторые особенности послеледниковой трансгрессии Балтийского моря. Тр.Океаногр.Комиссии АН СССР, т.12, 1961.

Павлидис Ю.А. Болдырев В.Л. К вопросу о послеледниковом развитии центрального участка южного побережья Балтийского моря.Тр.Океаногр.Комиссии АН СССР,т.12,1961.

Щербаков Ф.А. К истории развития северного и западного побережий Азовского моря в связи с образованием прибрежных морских россыпей. Тр.Океанографич.Комиссии АН СССР, т.12, 1961.

1623 R - Nov.1962 - 600

E/CONF.39/A/340
6 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A. 4. 2. 5

Republic of Korea

THE TIDAL POWER RESOURCES OF THE INCHON BAY, KOREA

By Tae Sang WON,
Ph. D., C. E., D. Eng.,
Professor and Chairman,
Department of Civil Engineering,
College of Engineering,
Seoul National University,
Seoul, Korea,
Member, National Academy of Sciences,
Republic of Korea, August, 1962

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

THE TIDAL POWER RESOURCES OF THE INCHON BAY, KOREA

by

Tae Sang Won, Ph.D., C.E., D.Eng.,
Professor and Chairman,
Dept. of Civil Engineering
College of Engineering
Seoul National University

Seoul, Korea
Member, National Academy of Sciences
Republic of Korea

I. INTRODUCTION

It is obvious that nations which enjoy the benefits of civilization today must develop power sources to create modern industries. This is especially true for a country such as the Republic of Korea. Electric power resources in the Republic of Korea, unfortunately, remain much less than the demand because Korea has been separated into two parts since 1945 - the north with substantial sources of power developed before that date, and the south, where the Republic of Korea Government has striven earnestly during the past seventeen years to develop new power resources.

Natural sites capable of being developed as power sources are plentiful in Korea. Among these natural resources, the world famous high tides of Inchon Bay on the western coast of Korea offer one large potential source of power. Tides in this region have a maximum range in excess of ten (10) meters. Substantial development of these tidal power resources should be capable of producing more than 2,000,000 K.W. of electricity.

II. TIDAL POWER RESOURCES OF THE REGION NEAR THE INCHON BAY

1. The Record of the Tidal Range in the Region and its Localities.

In the regions of the western coast of the Korean Peninsula, the tidal range is generally great. Especially in the regions near the Inchon Bay, between the districts of about 160 kilometers from north to southward, it is world famous in the point what the tidal range is extremely great. As the horizontal distribution of this district Table 1 which shows the tidal range and others at the various regions including islands, is shown here.

Table - 1

Value of the Tidal Ranges at the Regions Near the Inchon Bay

Region	Average H.W. interval	Tidal rise	Tidal range	Neap range
Mohang-ni	3^h : 34^m	6.51^m	5.88^m	2.82^m
Umu island	4 : 06	7.68	7.02	3.36
Soya island	4 : 17	7.41	6.72	3.12
Tokchok island	4 : 11	7.50	6.78	3.00
Daemui island	4 : 24	8.22	7.56	3.42
Asan (Hanjin)	4 : 25	8.79	8.10	3.84
Inchon harbour	4 : 32	8.58	7.98	3.54
Jumun island	4 : 48	7.95	7.26	3.36
Estuary of the Han River	--	9.60	9.00	--

The annual record of the tidal range at the Inchon harbour is illustrated in Table - 2.

According to Table - 2. the annual records show as follows:

Annual Max	10.4
Annual Min	2.9
Annual Average	6.2

The reason what the tidal range in the region near the Inchon Bay is extremely great may be described as follows. The tide, a sort of wave created in the deep ocean proceeds to the Yellow sea through the Ryukyu Islands, and proceeds to the Pohai Bay after passing the western coast of Korea and dragging the southern part of the Liaotung peninsula. When the wave reaches the western coast of Korea, the depth of the water in which it travels, suddenly becomes very shallow and also the width of the water surface becomes narrow and assumes a conical shape. Consequently, it appears that the phenomena of extra-high tidal ranges in Inchon Bay are due to the topographical and geographical locality of the region. It takes the tidal wave about 9 hours to get to Inchon Bay from the Ryukyu Islands. It appears that the mean tidal range is about 1.5m in the region of the Ryukyu Islands. Gradually, it increases in value as it travels north ward and local conditions then make it appear extra-large in the Inchon Bay region.

Table - 2

Annual Record of the Tidal Range at the Inchon Harbour
(unit in meter)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 am	---	4.1	---	4.3	5.8	7.5	7.0	7.3	8.1	7.9	7.1	6.7
pm	3.5	4.4	3.7	5.3	6.6	7.7	7.0	7.1	7.5	8.2	8.2	8.3
2 am	4.3	4.8	3.8	5.6	7.1	8.1	7.5	8.8	8.1	7.8	6.5	6.1
pm	4.0	5.5	4.0	6.7	7.7	8.1	7.4	6.8	7.6	8.1	7.7	7.7
3 am	4.7	5.9	4.2	7.2	8.2	8.4	8.9	8.2	7.9	7.4	5.8	5.6
pm	4.9	6.8	5.2	8.1	8.5	8.2	6.6	6.9	7.5	7.8	7.1	7.0
4 am	5.5	7.1	5.6	8.6	9.1	9.2	8.5	8.0	7.3	6.7	5.0	5.0
pm	6.0	8.0	6.6	9.1	9.1	7.3	6.6	6.9	7.1	7.2	6.1	6.0
5 am	6.4	8.2	7.1	9.5	9.3	9.0	8.3	7.6	6.6	5.8	4.1	4.5
pm	7.1	9.1	8.1	9.6	8.6	6.9	6.4	6.7	6.5	6.5	5.3	5.3
6 am	7.3	8.2	8.5	9.4	9.9	8.5	7.9	6.1	5.7	4.8	3.7	---
pm	8.1	10.2	9.2	9.8	9.3	6.4	6.2	6.3	5.8	5.6	---	4.6
7 am	8.1	8.8	9.5	10.2	9.6	7.9	7.2	6.4	4.7	3.7	4.4	5.2
pm	9.0	10.3	9.4	9.4	7.7	5.8	5.8	5.8	5.1	4.8	4.0	5.1
8 am	7.7	9.0	9.6	9.9	8.9	7.0	6.5	5.4	3.6	3.0	5.0	5.8
pm	9.8	10.1	10.4	8.5	6.7	5.0	5.3	5.1	4.4	---	5.1	6.0
9 am	7.9	8.8	9.9	9.1	7.9	6.0	5.7	4.4	---	3.9	6.2	6.8
pm	9.9	9.1	10.0	7.3	5.6	4.4	4.8	4.5	3.5	3.8	6.6	7.1
10 am	7.9	8.1	9.6	7.9	6.7	5.0	4.9	3.6	3.8	4.9	7.4	7.5
pm	9.5	7.8	9.1	5.8	4.6	3.9	4.3	---	3.9	5.2	7.9	8.0
11 am	7.6	7.2	8.8	6.6	5.5	4.2	4.2	3.5	4.8	6.2	8.4	8.2
pm	8.6	6.3	7.7	4.4	3.7	---	---	3.9	5.1	6.7	9.0	8.6
12 am	7.0	6.1	7.8	5.1	4.4	3.3	3.6	3.9	6.2	7.7	9.1	8.5
pm	7.5	4.7	6.1	3.2	3.1	4.2	4.3	4.3	6.5	8.2	9.6	9.1
13 am	6.3	5.0	6.4	4.0	---	3.6	3.7	4.9	7.5	8.7	9.3	7.6
pm	6.1	---	4.6	---	3.7	4.6	4.5	5.2	8.1	9.4	9.5	9.6
14 am	5.5	4.0	5.0	2.9	3.1	4.2	4.8	6.1	8.2	9.7	8.6	7.4
pm	4.9	3.6	3.2	3.4	4.1	5.1	5.0	6.4	9.2	10.1	10.1	9.2
15 am	---	3.8	---	3.2	3.8	5.0	5.3	7.4	9.5	9.3	8.0	8.3
pm	4.4	4.0	3.2	4.1	4.8	5.6	5.7	7.6	9.4	10.4	9.5	8.5
16 am	4.7	4.3	3.1	4.1	4.6	5.8	6.4	8.4	10.2	9.7	7.2	6.3
pm	4.4	4.8	3.5	5.1	5.5	7.2	6.5	8.6	9.9	10.2	8.5	7.6

Table - 2 (Cont'd)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17	am	4.7	5.0	3.6	5.1	5.6	6.7	7.2	9.6	10.0	8.8	6.1	5.6
	pm	4.9	5.7	4.4	6.0	6.3	6.8	7.4	8.6	9.9	9.6	7.3	6.5
18	am	5.2	5.8	4.5	6.1	6.4	7.4	8.1	10.1	9.3	7.7	5.0	4.8
	pm	5.6	6.6	5.3	6.8	6.9	7.3	8.1	8.9	9.3	8.5	5.9	5.4
19	am	5.8	6.6	5.5	6.9	7.1	8.9	9.2	9.9	8.1	6.2	3.9	4.2
	pm	6.3	7.2	6.3	7.3	7.4	6.7	7.6	8.9	8.2	7.0	4.8	4.4
20	am	6.4	7.1	6.4	7.6	7.7	8.9	9.6	9.3	6.5	4.7	3.3	3.7
	pm	7.0	8.4	7.1	8.8	7.7	7.0	7.9	8.5	7.0	5.6	3.9	---
21	am	6.9	7.1	7.1	8.5	8.8	9.0	9.5	9.3	5.0	3.5	---	4.1
	pm	8.3	8.3	7.6	7.6	7.1	7.0	7.8	7.7	5.6	4.4	---	3.3
22	am	6.4	7.4	8.0	8.4	8.8	8.7	8.9	6.8	3.5	---	4.1	4.1
	pm	8.2	8.2	7.9	7.6	7.0	6.7	7.4	6.7	---	3.0	3.7	3.7
23	am	6.7	7.6	7.9	8.6	8.6	7.2	8.0	5.4	3.6	3.6	5.6	4.6
	pm	8.2	8.0	8.1	7.3	6.6	6.2	6.9	5.6	3.3	3.3	4.5	4.5
24	am	6.8	7.4	8.2	8.2	8.2	7.4	6.7	4.0	3.7	4.3	5.4	5.2
	pm	8.0	7.5	8.0	6.7	6.1	5.7	6.2	---	3.6	4.1	5.4	5.3
25	am	6.7	7.1	8.2	7.8	7.5	6.4	5.6	3.9	4.5	5.1	6.1	5.8
	pm	7.7	6.8	7.6	6.0	5.4	5.4	5.6	3.9	4.5	5.2	6.2	6.2
26	am	6.5	6.5	7.9	7.1	6.7	5.6	---	4.1	5.4	6.0	6.7	6.5
	pm	7.0	5.9	6.9	5.0	4.8	---	5.0	4.2	5.5	6.1	6.9	7.0
27	am	6.1	5.8	7.3	6.2	5.9	5.0	4.6	4.9	6.4	6.7	7.1	7.1
	pm	6.2	4.7	6.0	4.1	4.5	5.4	4.8	5.0	6.4	6.8	7.4	7.7
28	am	5.5	5.1	6.5	5.3	---	5.2	4.8	3.7	7.1	7.3	7.4	7.5
	pm	5.3	3.7	4.9	3.7	5.2	5.7	5.1	5.8	7.2	7.5	8.5	8.7
29	am	4.9	---	5.6	---	4.8	5.7	5.4	6.5	7.6	7.7	6.9	6.9
	pm	4.4	---	3.9	4.7	5.6	6.2	5.7	6.6	7.7	7.8	8.6	9.0
30	am	4.5	---	4.9	4.5	5.6	6.4	6.2	7.2	8.5	8.1	6.9	7.1
	pm	3.6	---	---	5.5	6.3	6.7	6.2	7.2	8.0	8.4	8.5	9.0
31	am	---	---	3.7	---	6.5	---	6.8	8.7	---	7.3	---	7.0
	pm	3.7	---	4.3	---	7.1	---	6.8	7.2	---	8.4	---	8.6
max		9.9	10.3	10.4	10.2	9.9	9.2	9.6	10.1	10.2	10.4	10.1	9.0
min		3.5	3.6	3.1	2.9	3.1	3.9	3.6	3.5	3.3	3.0	3.3	3.3
aberage		6.4	5.6	6.6	6.5	6.5	6.5	7.1	6.5	6.6	6.7	6.6	6.5

Topographical or geographical characteristics of the region near the Inchon Bay, are illustrated by the following facts. The sea shore of the region had been created by the sinking of the land for a long time in the past. For this reason, we can establish the fact that there are numberous zigzags in the sea shore line, innumerable islands, the depth of water is generally very shallow, the topography of the region forms a conical shape and creates numerous creeks. It seems to the author that these topographical or geographical localities account for the extremely high ranges of tide is the region.

2. Selected Tidal Power Sites and Estimated Output.

As stated above, in the regions near the Inchon Bay, there exists numerous good conditions to develop the tidal power resources in the topographical and geographical localities having an extra-large tidal range. Therefore, it may be said that there are numerous good tidal power sites in the regions near the Inchon Bay.

Among these, a project of the Kangwha Island established by some Japanese engineers in earlier days (about 1923) is illustrated briefly in Table - 3. In this project, the following data were adopted.

(a) Location of the Projects Site:

The district surrounded by the sea shore of Hado-Myun and Kilsang-Myun, Kanghwa County, Tongkom Island, Seo Island, Yongchong Myun, Puchon County, and the Hwangsam Island, Kimpo County.

(b) Tidal Range:

By the record of 1923
For rising tide: max 9.78 m , min 3.06 m
For ebb tide : max 9.45 , min 3.45

There are 6 projects (A, B, C, D, E, F) by the type of the systems, number and capacity of the tidal reservoirs etc.

We can recognize by Table-3 that it would be profitable to adopt the project E or F - single reservoir system-than the others to get cheaper and a more plentiful amount of electric power, even though there may be inconvenience in the point of unequal and intermittent production in the size of the produced electricity. (Vide Fig. 1)

In addition to the region near the Kanghwa Island mentioned above, there are numerous good tidal power sites in the western coast as stated above. Above all, the following sites are considered to be good sites to develop sooner or later, and reconnaissance, partially actual surveys, and also partially geological survey were made for them by the Korea Electric Power Company several years ago. Some French engineer was joined in the recommaissance. These data are illustrated in Table - 4. The producible outputs were also estimated as the values in Table - 4. (Vide fig. 2)

Table - 3

Tidal Power Project at the Region Near the Kanghwa Island

Type of Systems	Double Reservoir System				Single Reservoir St.	
	A	B	C	D	E	F
Number of Reservoirs	2	2	2	2	1	1
Total Area of Reservoirs (Chongbo)*	2,498	1,511	1,511	1,511	1,511	1,511
Higher Reservoir	776	776	776	776	--	--
Lower "	735	735	735	735	--	--
Spare "	985	--	--	--	--	--
Avilable Head (m)	10.5-6.75	1.95-5.85	1.8-5.4	1.8-5.4	1.8-5.4	1.8-5.4
No. of Turbines (Set)	56	20	8	8	20	20
Output Capacity						
max (M.W.)	10.425	9	36.12	21.12	47	47
normal	7.5	6.5	15	17.6	44	44
average	4.5	4.8	21.12	7	11	11
Annual Producible Power (1,000KWH)	39,420	42,048	185,022	61,320	96,360	96,360
Total Cost ($1000)	4,225	2,250	4,325	2,750	4,000	4,270
Unit Cost ($ per K.W.)	544.5	346	Steam 105 Tidal 165.5	156.5	91	97
Maintenance annual Cost ($1000)	119.5	83	1,248.26	125	150	150
Profit Apportionment(%)	10	10	10	10	10	10
Necessary Electric Rate (Cent/K.W.H.)	1.4	0.735	0.85	0.655	0.57	0.6

* 1 Chongbo equals to 1 hectare approximately.

Table - 4

Producible Outputs for the Selected Sites

	Name of Sites	No. of Proposed Reservoirs	No. of Gauge Stations	Productible Outputs(K.W.)
a	Sihung	2	2	113,000
b	Namyang	2	2	61,000
c	Tangjin	1	1	125,000
d	Karorim	1	1	163,000
e	Asan & Punhyang	1	1	174,000
f	Anhung	2	2	104,000
g	Sosan	1	1	15,000
h	Chonsu			347,000
	Kanghwa-Inchon			200,000
	Total			1,302,000

Geological survey were made at the sites of Asan and Punhyang. Describing briefly the results, the geological formation generally consists of 3 - 6 m of topsoil and clay, 2 - 4 m of sand and gravel layer, 3 - 6 m of soft and crushed rock, 4 - 9 m of hard rock bed below of the bottom of the sea. Therefore we can find the rocky bed at the depth of 8 - 16 m below of the bottom of the sea. Henceforth it may be said that the geological condition is also very favourable to construct dams with cheaper cost.

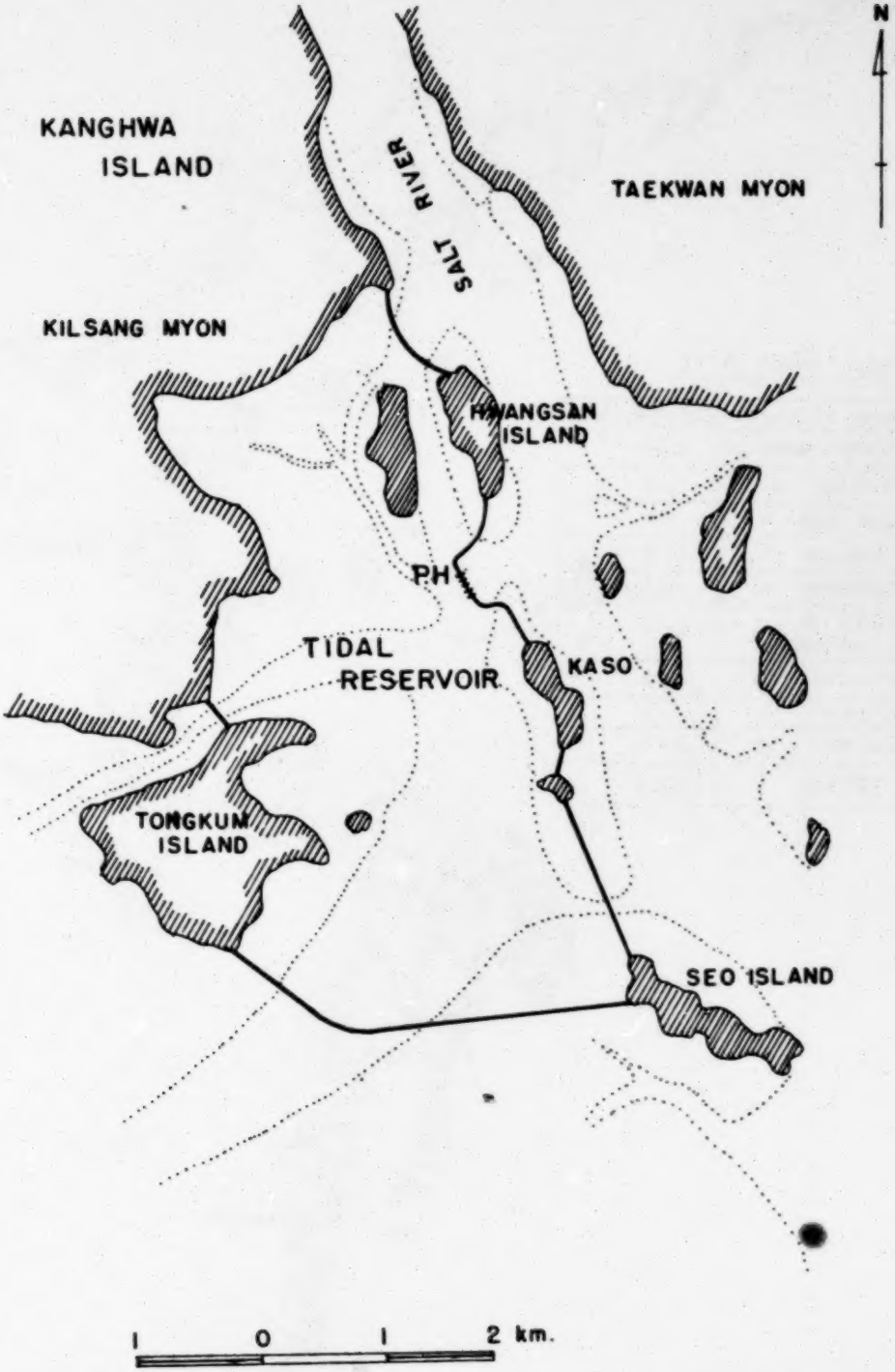
III. CONCLUSION

As natural power-resources in Korea, of course, the water power resources of the rivers would be considered to be promising. But the most parts of the excellent water power sites are located in the North Korea. Moreover, it is necessary to construct high dams and to build large reservoirs as far as possible to develop the water power sites in Korea viewing the meteorological and hydrological characteristics of the rivers in Korea. To develop the water power sites in such a manner, it needs huge amount of money, and on the other hands, it produces a reduction in cultivated land. This is a serious problem in an agricultural country like Korea. Also when high dams and large reservoirs are constructed in a locality such as Korea, the output decreases suddenly or falls to zero during the "winter or summer dry season". Therefore, electric power rates in Korea are necessarily higher than in other countries.

On the contrary, in the tidal power generation, we can eliminate the effects of a sudden decrease of output during the winter or summer dry season, even we feel the deficiency of the "unequal magnitude of the output" each hour.

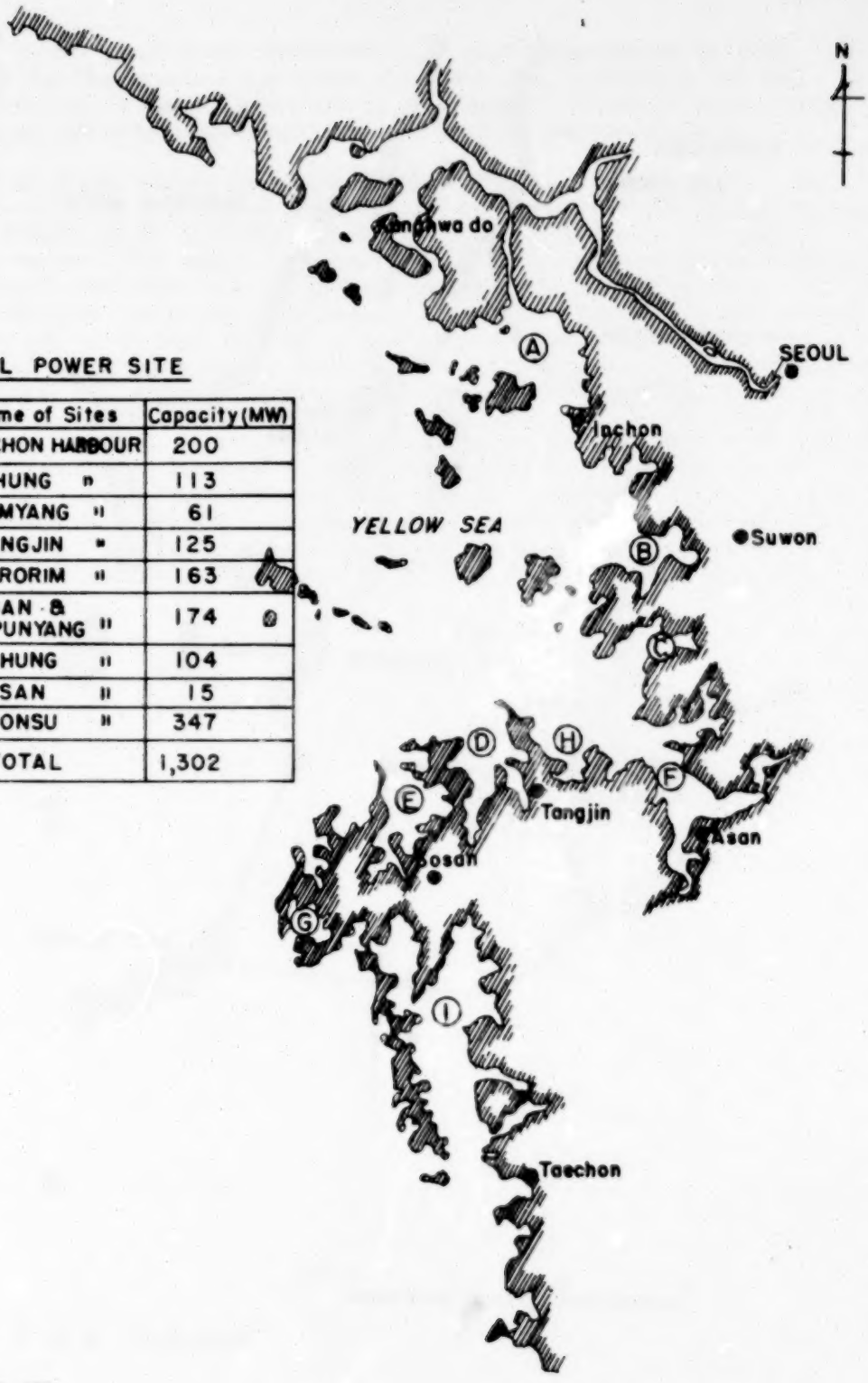
In the tidal power development, it needs huge amount of cost mainly for the construction works under the sea, especially for the construction of dams. Therefore it is necessary to select such a site where we can reduce the length of dams by its local conditions.

As stated above, the western coast of Korea, particulary in the region from 160 kilometers above the northern shore of the Inchon Bay to the northern shore of South Chungchong Province, there is not only a world famous tidal range - greater than 10 m, but also adequate favourable local conditions i.e. numerous zigzags of the sea shore which forming adequate creeks and bays bearing innumerable islands in the estuary of the creeks or bays just as if forming a natural break-water. The depth of water generally is very shallow for a considerable distance from the shore. It would be sufficient to say that local conditions of the region near Inchon Bay would shorten the length of dams and reduce the construction cost, in other words, they would form excellent tidal power sites. Moreover, it seems to the author, that the construction cost would be cheaper because various new methods of construction and improved effective equipment including "Prepact Concrete" have recently been invented and developed. Therefore it can be said that these tidal resources sites are waiting for the world's attention to be developed in practice.



PROJECT E & F

FIGURE I



TIDAL POWER SITE

	Name of Sites	Capacity (MW)
A	INCHON HARBOUR	200
B	SIHUNG "	113
C	NAMYANG "	61
D	TANGJIN "	125
E	KARORIM "	163
F	ASAN & PUNYANG "	174
G	ANHUNG "	104
H	SOSAN "	15
I	CHONSU "	347
TOTAL		1,302

FIGURE II-

1322 E - Nov. 1962 - 1,600

E/CONF.39/A/341
6 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A. 5. 2. 1

Tanganyika

MINERAL EXPLORATION IN THE WESTERN RIFT, TANGANYIKA

By J. H. G. FUCHTER,
Ph. D., A. M. I. M. M.

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

MINERAL EXPLORATION IN THE WESTERN RIFT (TANGANYIKA)

J.H.G. Fuchter, Ph.D., A.M.I.M.M.

INTRODUCTION

1. Between 1956 and 1960 an extensive mineral exploration programme was carried out over an area of 34,000 square miles in the Western Rift in Tanganyika (See figure 1).

2. This area, situated in the Lake Rukwa-Lake Tanganyika region, is in one of the most remote and under-developed parts of Africa. Its topography is characteristic of an area which had been subject to rift faulting; mountainous in places with unrelieved plains elsewhere. Vegetation varies from swamp to open savannah and parkland, from dry to wet forests.

3. Herds of big game were frequently encountered in many parts of the concession area. Hazards to health, particularly malaria and sleeping sickness, had to be carefully watched. Communications were poor or non-existent.

4. The area was unfamiliar and largely unmapped and the geology little understood. Mineralization, most of it uneconomic, was known to exist and included gold, lead, copper and nickel.

5. The mineral exploration programme carried out in this area included the use of most of the modern prospecting techniques.

6. In the following pages the methods employed and some of the results obtained and also a few important aspects of organization, personnel selection and expenditure are discussed.

II. ORGANIZATION AND STAFF

7. Prospecting of the concession area of 34,000 square miles was completed in four-and-a-half years by a staff of eleven field geologists, eighteen field assistants, three senior geologists (including the geologist-in-charge), one mineralogist-petrologist, one photo-geologist, one geochemist, two geochemical laboratory assistants, two administrative assistants, one motor mechanic, one pilot and one driller, and an average labour force of five hundred. (See figure II for the staff organisation).

8. Having a field force of eleven geologists and eighteen field assistants working in one concession area and whose efforts entailed the collecting of 10,000 soil and stream sediment samples and 500 to 1,000 panned concentrates per month, required a rigid standardization in the method of working and the representation of results. It would otherwise have been impossible to correlate and synthesize all incoming information.

9. A well-organized and standardized numbering system for samples, sample lines, sample blocks and areas was introduced for the geochemical soil sampling programme. Ground geophysical surveys were tied to this system, while a similar system was used for stream sediment sampling. In tackling a mineral exploration programme over such a large area, due regard had to be given to the principle of having a well-equipped base within or very close to the area concerned for the following reasons :-

10. (a) It is of the utmost importance that geochemical samples, panned concentrates and rock samples for mineral identification reach the laboratories as quickly as possible and that results are plotted and returned to the field parties while they are still operative in the areas concerned.

(b) Proper technical and administrative control can be exercised.

(c) It gives the field staff the opportunity of visiting base periodically. This is advantageous from the point of view of compiling reports, preparing maps, discussing problems with colleagues and obtaining information generally. It also contributes towards maintaining morale and also gives the field men an opportunity to live for a short period in a more congenial environment - a welcome break from harsh field conditions.

11. The careful selection of field personnel is particularly important if they are to withstand the tiring physical conditions and boredom of repetitive routine field procedure. The integrity, perseverance and enthusiasm of the professional geologist can usually be relied on but the importance of conforming rigidly to field procedures and standards often escapes the field assistant.

III (a) GEOLOGICAL INVESTIGATIONS.

12. It was apparent, at the inception of the programme, that a geological map of the area was essential, even although such a map depicted geological features which were not fully identified.

(i) Photo-geological mapping.

13 To get an overall picture of the geology as quickly as possible, a photo-geological interpretation was combined with a field reconnaissance. By sampling the geology on the ground and comparing it with air photographs it is reasonable to assume that whole areas shown on the photographs as having similar features, such as surface weathering, vegetation and colour, are similar to the sample. Furthermore, air photographs exhibit structural features, such as lineations, folds and faults, which cannot be seen easily, if at all, on the ground.

14 The field reconnaissance was completed in five months. It then took about another eight months before all photographs of the area concerned were re-interpreted in the light of the field evidence. Final maps were then compiled.

15 The final product was a geological map on the scale of 1:50,000, which showed geological features with which the known mineralization could be correlated.

(ii) Regional mapping.

16 Subsequent geological work consisted of traversing areas on foot at suitable intervals. For example, an area shown by air photographs to be covered entirely by superficial deposits which obscured bedrock, could be traversed at intervals of one mile to determine, for example, whether variations in colour and texture of the cover would reveal something about the bedrock. On the other hand, an area of exposed bedrock of obvious economic

potential would be traversed at intervals of a quarter of a mile or less.

17. An area of other exposed rock, however, considered to be of little interest, would be mapped in conjunction with geochemical drainage reconnaissance sampling and panning of river gravels. Since sampling and panning were mostly done by field assistants, only a few selected widely spaced watercourses, preferably cutting across strike, were mapped.

18. In this way the photo-geological map was improved, resulting in a better understanding of the geological history. This in turn provided a better background for assessing the economic potentialities of the concession area.

(iii) Detailed mapping.

19. This type of geological work was restricted to areas of special interest and was usually undertaken in conjunction with detailed ground geophysical work over geochemical and airborne geophysical anomalies and also in areas of known mineralization. It usually consisted of traversing at intervals of 200 feet and was done mainly during the latter stages of the exploration programme. Approximately 0.2% of the total concession area was investigated in this way.

(b) Geochemical investigations.

20. Geochemical prospecting in the Western Rift entailed the collection of 290,000 samples, which in turn involved 1,350,000 individual geochemical tests. The laboratory was geared to undertake 80,000 tests per month.

(i) Drainage reconnaissance sampling.

21. Geological mapping in the Western Rift was expected to facilitate the delimitation of areas of possible mineralization potential. However, it was also fully realized that geological reasoning could be faulty and that economic mineralization might well be present in an area in which the geological evidence available at that time did not appear favourable.

22. It was therefore decided to sample the drainage of the entire concession area systamatically with the exception of the Recent lake sediments of the Rukwa Rift Valley. In this manner the distribution of base metal traces in the drainage could be mapped, with the object of delineating areas of interest for more detailed prospecting work.

23. A total of 90,000 stream sediment silt and mbuga (seasonal swamp) clay samples was collected at half mile intervals from the drainage courses. The samples were dried where necessary and then lightly ground and sieved through 80 mesh screens. The undersize fraction was despatched to the laboratory at base for analysis.

24 The samples were analysed by the following methods :-

a. The dithizone cold extraction method (detection limit ± 0.5 parts per million) for available copper and zinc.

b. By perchloric acid extraction and subsequent colorimetric analysis (detection limits 5 to 15 parts per million), for total copper, lead and nickel.

25. Analytical results in parts per million were plotted for each metal adjacent to each sample site on separate 1:50,000 scale location maps (DOS sheets, published by Directorate Overseas Services, London). An empirical set of values, based on the consideration of a large number of values from differing drainage types and geological environments, was chosen for each metal to define the background, threshold, possible and probable anomalous limits. The anomalous and threshold values were then contoured and transferred to separate maps (1:500,000) of the concession area.

26. These maps show the presence of well-defined anomaly patterns for nickel copper, lead and zinc. The high-order nickel anomalies appear to be related to ultrabasic intrusives and generally have coincident copper anomalies. Both cold extraction copper and zinc anomalies have a widespread distribution. Cold extraction copper confirms total copper anomalies in most cases, but the former is much more widespread. Many cold extraction copper anomalies are not supported by total copper.

27. Threshold and possible anomalous nickel and copper values are usually associated with mafic rock types.

28. In some cases higher values for one or two particular metals appear to be related to areas underlain by certain rock types. For example, higher total lead values are associated with the more widely distributed rhyolitic lavas, granite porphyries and granites. On the other hand, the occasional carbonatitic and associated alkaline rocks are outlined either by higher zinc values or by higher lead values.

29. It is of interest to note that, with two exceptions, high-order anomalies occur in areas which on geological grounds were considered to have greater mineralization potential than others.

30. The two exceptions were a copper and a nickel-copper anomaly in areas underlain by younger sediments. These were assumed to be of little importance from the economic point of view. Follow-up work on these anomalies established that they were not related to any form of mineralization.

31. One high-order copper-nickel anomaly was found to be related to mineralization which unfortunately appeared to be uneconomic.

(ii) Systematic soil sampling was limited to (a) areas of known mineralization, (b) areas which appeared to be economically favourable on geological grounds, and (c) areas in which anomalies were found by drainage reconnaissance sampling.

32. A total of two thousand square miles was sampled in this manner, involving the collection of 200,000 samples.

33. Selected areas were divided into blocks of 16,000 feet square. For this purpose base lines were cut on a 16,000 foot grid and accurately surveyed. Tie lines at right angles to the base lines were also cut and surveyed at 32,000 foot intervals. Both base lines and tie lines were blazed with red or yellow paint. Hardwood stakes were inserted along the base lines at 200 foot intervals. Base lines were plotted on air photographs and on 1:50,000 location maps (DOS sheets). Sampling was done along lines 2,000 feet apart at right angles to the base line with a sample station interval of 200 feet. Individual sample lines within one block were run by compass and also blazed with paint and numbered 0, 2, 4, 6, 8, 10, 12, 14, prefixed by the block number. Samples were taken at a depth of 18 inches and were consecutively numbered from 0 - 30 along each line (in the same direction throughout one area). Samples from one line were put in one box which carried the number of the DOS location sheet within which the sampled block occurred, the block number and the line number. This information was also written on the sample packets, together with the relevant sample number.

34. It will be appreciated that the sampling direction was dependent on mineralized (if known) or favourably considered geological and structural trends.

35. The layout of a systematic soil sampling grid was supervised by a geologist but carried out by two or more field assistants who, together with labourers, collected the samples, noting the type of soil, vegetation, topography and the absence or presence of rock outcrops. Geologists generally only mapped lines where outcrops occurred.

36. Samples were assayed by the same methods mentioned in paragraph 34 above.

37. Analytical results were plotted on block maps on a scale of 1:10,000 for each 16,000 feet square block, by two plotters attached to the geochemical laboratory. Geological information and soil types were mapped on the same scale but on a different map. Plotted analytical results were contoured and main geochemical trends and anomalies were transferred to 1:50,000 maps. Maps showing soil types, geology and structural features were also compiled on a scale of 1:50,000.

38. Although known mineralization was generally clearly outlined in the Mpanda area by systematic soil sampling, failure to locate a sizeable lead anomaly 6 miles north-west of Mpanda Mine should be mentioned. This lead occurrence was found with the aid of a local guide. It consisted of a small hole containing some galena float. Detailed soil sampling on a grid of 50 feet square established anomalous lead values of up to 6,000 parts per million over a distance of 500 feet. Subsequent pitting established the presence of weak lead mineralization in a northwest-southeast trending shear zone.

39. Systematic soil sampling had failed to establish the presence of this mineralized shear zone. Even fill-in sample lines at 1,000 foot intervals did not indicate the presence of this mineralization, which admittedly was uneconomic but could have been significant.

40. The reason for this failure was due to the fact that sample lines were in this case parallel to the mineralized trend. Systematic soil sampling should preferably be carried out along sample lines at right angles to each other, but this would increase costs considerably. Furthermore, the interval of 2,000 feet between sample lines might be too great and in some cases an interval of 1,000 feet would undoubtedly be warranted. The manner in which such a programme is conducted depends very largely on the judgement of the geologist-in-charge.

(iii) Detailed soil sampling was done over the following :-

a. Known mineralized occurrences in an attempt to find extensions.

b. Anomalies found by systematic soil sampling, in order to delimit them more accurately. This facilitated the siting of trenches, pits and boreholes.

c. Geophysical anomalies.

41. Sampling of this kind was usually done along sample lines at intervals of 200 feet with sample station intervals of 50 feet. However, in some cases such as described in paragraph 38, sampling would be carried out in much greater detail.

42. Sampling was also extended to bedrock. For this purpose pits with a diameter of 30 inches were dug down to bedrock, sometimes at a depth of 60 feet or more. These pits were sampled over lengths of 2 feet and results were plotted in vertical sections and contoured. Peak anomalies could be very accurately defined in this manner, thereby facilitating borehole location.

(c) Heavy mineral investigations.

43. This type of work consisted of the systematic collection of panned concentrates from stream gravels in conjunction with geochemical drainage reconnaissance sampling described in paragraphs 22 and 23.

44. Stream gravels or coarsest available stream sediments were sampled at intervals of one mile along all watercourses as part of the geochemical sampling programme. Samples weighing ten pounds each were collected or else panned on the spot if water was available. Concentrates were put in specially designed aluminium containers and sent to the mineralogical laboratory at base for identification.

45. By sampling the entire drainage system at intervals of one mile a sampling density of about one panning per square mile was attained.

46. Concentrates were examined microscopically by a mineralogist and the relative abundance of economically important minerals assessed by assigning them numbers, e.g. 1 for trace, 2 for present, 3 for abundant and 4 for predominant.

47. Each economic mineral also received a symbol, for example, W for tungsten-bearing minerals. The symbol and the relative abundance number were plotted adjacent to sample location on maps on a scale of 1:50,000 (DOS sheets).

48. In this way areas could be outlined where a relative concentration of economic important minerals occurred in panned gravels. Subsequent work consisted of closer sampling of watercourses in such areas to delimit areas of potential interest more accurately. In the third stage soils were panned on a closely spaced grid until the source of the mineral(s) was found.

49. Panning of stream sediments is a well-established, orthodox prospecting technique which can still be considered one of the most effective available to the exploration geologist. However, it also has its limitations. In large peneplained areas with mature, sluggish and senile drainage this method will lose much of its effectiveness in the search for sulphide minerals. Certain other minerals tend to slime easily and therefore cannot be traced very far from their source. It is nevertheless surprising that, even in peneplained regions, areas of relative interest can be outlined clearly by this method.

(d) Geophysical investigations.

(i) Airborne geophysical prospecting was extensively carried out in the Western Rift.

50. Ideally airborne geophysical maps should be available before systematic field work begins. However, it is obvious that they would be somewhat lacking in value due to the scanty geological evidence available in the initial stages of the programme. The value of such geophysical data will be enhanced with increased geological knowledge, thereby facilitating the selection of areas for intensive investigation.

51. The value of extensive airborne geophysical data lies not only in direct prospecting for magnetic bodies (for example, containing iron, nickel, platinoids or chromium) or conductive sulphides (such as those of nickel, copper and lead) or radioactive minerals, or as aids to mapping outcrops and structures, but in offering a challenge to the field geologist to explain the measurements, to re-examine his observations and interpretations and so to seek mineralization where otherwise he might have missed it.

52. The selection of areas for airborne geophysical examination was made on geological grounds and on evidence of probable mineralization. Such areas, totalling 10,000 square miles, were flown by a D.C. 3 aeroplane at 500 feet above ground level and on courses at intervals of a quarter of a mile across the regional geological trend. This aircraft was fitted with a scintillation counter, a proton free-precession magnetometer and electro-magnetic equipment, the receiver coil of which was placed in a "bird" connected to the aircraft by a cable 500 feet in length. The magnetometer was carried at the end of a stinger projecting from the tail of the aircraft. Results were compiled and plotted on maps on a scale of 1:50,000.

53. Magnetic maps were found to be very useful. Basic, ultrabasic and carbonatite bodies were clearly outlined. Structural trends showed up well and facilitated geological interpretation.

54. Results of the scintillation counter survey were disappointing, as soil cover (even where only a few inches thick) had a masking effect which tended to control the appearance of the plotted radiometric results. In consequence, little importance was attached to the radiometric maps. However, carbonatites appeared to be associated with well-defined anomalies whereas weak anomalies usually reflected the presence of granitoid outcrops.

55. The electro-magnetic survey measured the quadrature component at frequencies of 400 and 3,100 cycles per second. The quadrature component at 400 cycles per second was plotted when anomalous, whereas the ratios between that and the quadrature component at 3,100 cycles per second were listed.

56. The results were disappointing as far too many anomalies were found. They were difficult to assess as no criteria could be established to distinguish those anomalies possibly related to mineralization from those caused by electrolytes in clays and swamps. Several of the more interesting airborne electro-magnetic anomalies were followed up by ground electro-magnetic surveys, which in all cases failed to confirm the presence of the airborne anomalies. Many factors may be the cause of these discrepancies, such as change in the position of the "bird" in relation to the aircraft, and/or to the presence of extensive clay soil cover and seasonal swamps, the hosts of conducting electrolytes. These conditions prevail over a great part of the African continent and it is felt that more research in airborne electro-magnetic surveying should be carried out before being used for prospecting large unknown areas. In this connection it might be interesting to experiment with different frequencies and other types of aircraft, capable of flying at considerably less than 500 feet above ground level.

(ii) Ground geophysical survey.

57. This type of survey was concentrated on (1) locating and checking of anomalies detected by airborne geophysics, (2) small areas which were considered to have potential as a result of geochemical work, and (3) known mineral occurrences in an attempt to find extensions. These surveys were done with torsion magnetometers and electro-magnetic equipment.

58. a. Magnetometer surveys were carried out mainly to locate anomalies detected by airborne magnetics. In a few cases this technique was also used in an attempt to find a magnetic trend which could possibly be associated with a geochemical anomaly. Without exception airborne magnetic anomalies were confirmed by ground magnetometer surveying and this was of particular interest in areas lacking outcrops. All magnetic anomalies confirmed in this manner appeared to be associated with ultrabasic intrusives.

59. Ground magnetometer work done in conjunction with detailed geochemical surveying did not appear to be of much use. An association of geochemical and magnetic "highs" was rarely encountered and in the few cases where there was some form of agreement, it was not due to the presence of mineralization.

60. b. Ground electro-magnetic surveying was done over a number of airborne anomalies and in conjunction with detailed soil sampling and ground magnetometer surveys. A system of portable horizontal coils was used. Receiver and transmitter coils were 300 feet apart. A series of lightweight portable silver-zinc batteries served as a source of energy (12 volts). In-phase and quadrature components were measured at a frequency of 416 cycles per second at 50 foot intervals along lines - usually 200 feet apart - which coincided with the detailed soil sampling grid.

61. Results were plotted in parallel profiles. Significant anomalies were never detected, but this might be due to absence of sulphides in sufficient concentration. Anomalous trends were observed and in one case drilling established the presence of a graphite zone associated with such a trend

IV. CASE HISTORIES.

62. In the foregoing pages the various exploration techniques were discussed under separate headings. However, it should be stressed again that these techniques were closely integrated and often complementary. For example, geological interpretation benefited by the availability of magnetic maps, but on the other hand, interpretation of magnetic maps became much easier where the geology was better understood. In addition, geophysical results could only properly be assessed when sufficient geological information was known.

Two case histories illustrating the above will be described.

(a) Rungwa River area

63. In the initial stages of the exploration programme in the Western Rift, preliminary magnetic maps of the Rungwa River area (north-east of Lake Rukwa) showed the presence of a series of marked, parallel, north-south magnetic linears which looked interesting.

64. It was decided to send a field party to check the significance of the magnetic picture. For this purpose a track of 60 miles had to be made. On arrival, a site for an airstrip was selected and after six weeks the latter was being used. Geological mapping soon established that the magnetic linears

linears were related to vertical basic dikes. It was also found that these dikes were intrusive into a metamorphosed complex consisting of granitic gneisses and amphibolites. These metamorphosed rocks and the later intruded basic dikes were subsequently metasomatized, a process associated with a granitization front, involving the introduction of potash and silica. This geological picture appeared to be identical to that known to exist in a gold-copper-lead mineralized area 100 miles to the south-east (Lupa Gold Field). This justified a systematic soil sampling programme and a systematic examination of the heavy mineral contents of the various watercourses. Heavy mineral investigations established the widespread occurrence of traces of gold and scheelite. Systematic soil sampling did not outline high-order anomalies, but one lead anomaly was considered to be of more than passing interest. Detailed soil sampling combined with a ground electro-magnetic survey, heavy mineral investigations and subsequent pitting and trenching established the presence of secondary lead minerals in a sheared graphite-bearing pegmatitic zone.

65. Although this mineralization was uneconomic it demonstrated that the methods employed were capable of detecting even feeble mineralization.

(b) Kapalagula Area

66. Even in the earlier stages of the exploration in the Western Rift, the Kurigwe Bay area was considered to be of likely economic interest.

67. Nickel and copper sulphides were known to be present in the Kapalagula ultrabasic complex on the eastern shore of Lake Tanganyika. Previous exploration had shown this occurrence to be uneconomic, but it was known from a few scattered reconnaissance traverses that additional ultrabasic intrusives, potential host rocks for copper, nickel, chrome and platinoid mineralization, were present in the area. The very rugged topography precluded the use of airborne geophysical methods. Outcrops were scarce. A party of two geologists and two field assistants mapped the area on a regional scale and carried out a drainage reconnaissance sampling programme. The results of the latter clearly outlined a number of high-order nickel and copper anomalies, some of which were known to be associated with ultrabasic intrusives. One of the most striking anomalies was found south-east of Kapalagula in an area of no outcrop and this suggested a possible extension of the mineralized Kapalagula ultrabasic complex. The magnitude of the anomaly over the possible extension was considerably greater than over the mineralized Kapalagula intrusive itself. Subsequent systematic and detailed soil sampling combined with detailed geological mapping confirmed the presence of an extension of the Kapalagula ultrabasic intrusive. The soil sampling anomaly was well-defined and of a very high order. A ground electro-magnetic survey showed only a few vague anomalous trends which did not coincide with any geochemical anomalies. Pitting across geochemical peak anomalies down to a depth of 60 feet revealed the presence of geochemical values of 2 - 3% nickel and 2% copper in clays but only a few patches of disseminated pyrrhotite and chalcopyrite in weathered bedrock, which was uneconomic. Drilling did not establish the presence of any economic mineralization. The high values found during systematic soil sampling and subsequent detailed soil sampling and pitting are obviously the result of intensive and deep weathering which caused secondary enrichment of nickel in the clay soils. Although no ore bodies were found, the techniques employed helped to detect previously unknown mineralization.

V. EXPLORATION EXPENDITURE

68. Having attempted to describe an extensive mineral exploration programme in an unfamiliar and little known area, it might be of interest to mention the expenditure involved.

69 A total of £1,067,868 was spent, which can be detailed as follows:-

Administration Expenditure - Base	£	18,670
Administration Expenditure - Head Office		113,989
Labour		49,205
Aircraft		45,385
Camping Equipment		12,223
Drawing Office		9,767
Drilling		32,716
General		98,108
Geochemical Laboratory		36,449
Geophysical Survey		187,681
Housing and Maintenance		20,790
Mineralogical Laboratory		33,195
Photogeology		54,178
Radio Communications		2,143
Rental Concession Area		33,500
Track Building and Airstrips		14,216
Salaries (field personnel)		176,286
Travelling (field personnel)		7,269
Vehicle Maintenance		63,380
Loss of sale of Capital Equipment		58,718
	£	1,067,868

70. From these figures it can be seen that the geophysical work accounted for a substantial part of the total expenditure. Most of this was for airborne surveying - less than 5% was spent on ground surveying.

71. It is somewhat unfortunate that from the available figures no conclusion can be drawn about the costs of various individual field prospecting techniques, like soil sampling, drainage reconnaissance sampling and heavy mineral investigations.

72. Geochemical assaying is cheap and amounts to an average of 6d. per test per element. As each sample was tested for copper, nickel and lead by total extraction and for copper and zinc by cold extraction, geochemical testing cost about 2s. 9d. per sample.

73. Investigation of heavy mineral concentrates is rather expensive and averages about 30s. per concentrate. Expenditure for mineralogical investigation could be lowered by testing heavy mineral concentrates first by spectrographical methods for the presence of economic important elements. Subsequent mineralogical investigation could be restricted to concentrates containing such elements.

74. Overhead costs are relatively high. This is understandable as only large mining groups with the necessary technical know-how and financial resources are in a position to tackle mineral exploration on such a large scale.

Location Sketch Map

WESTERN RIFT CONCESSION

Figure I

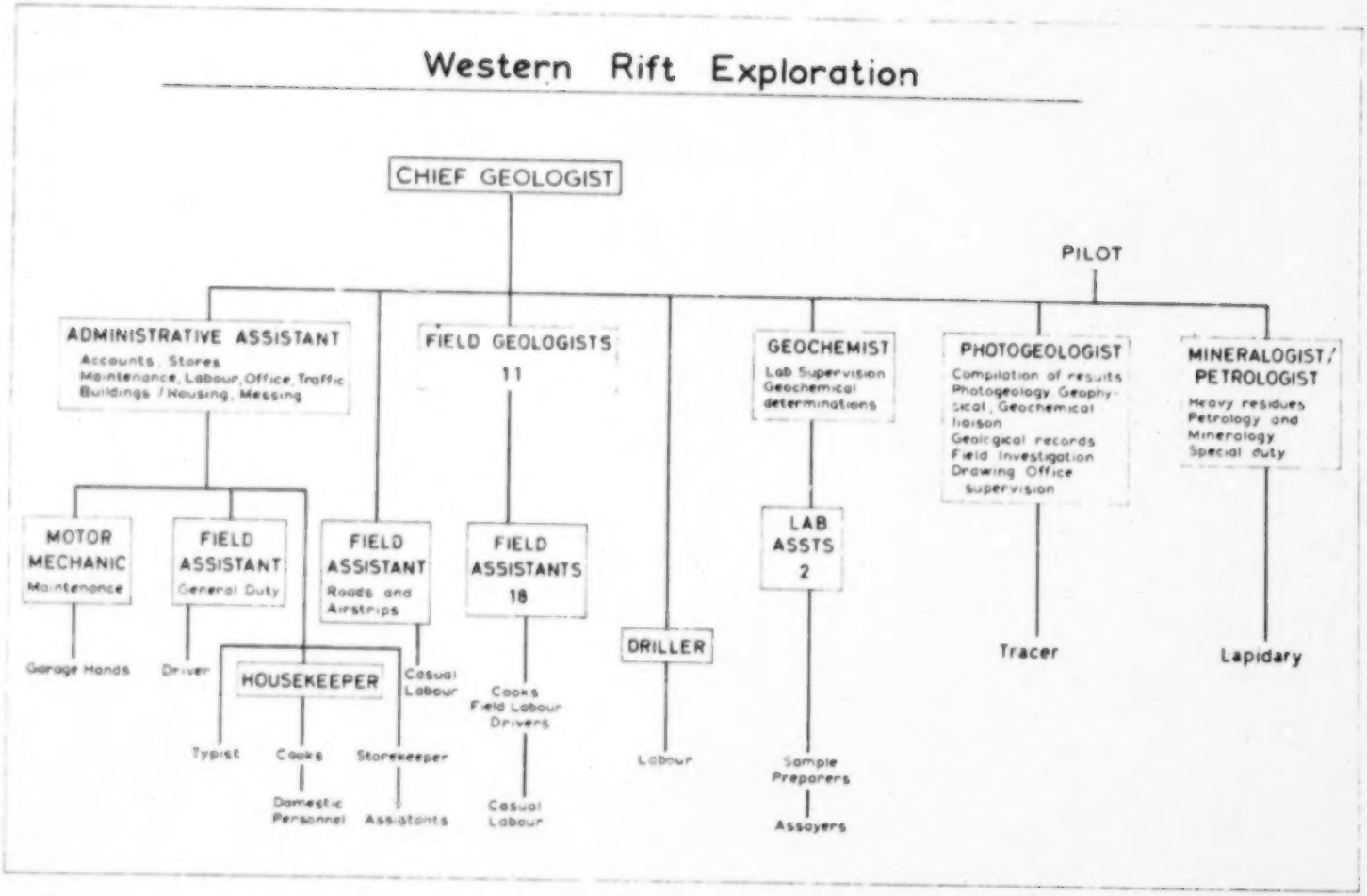
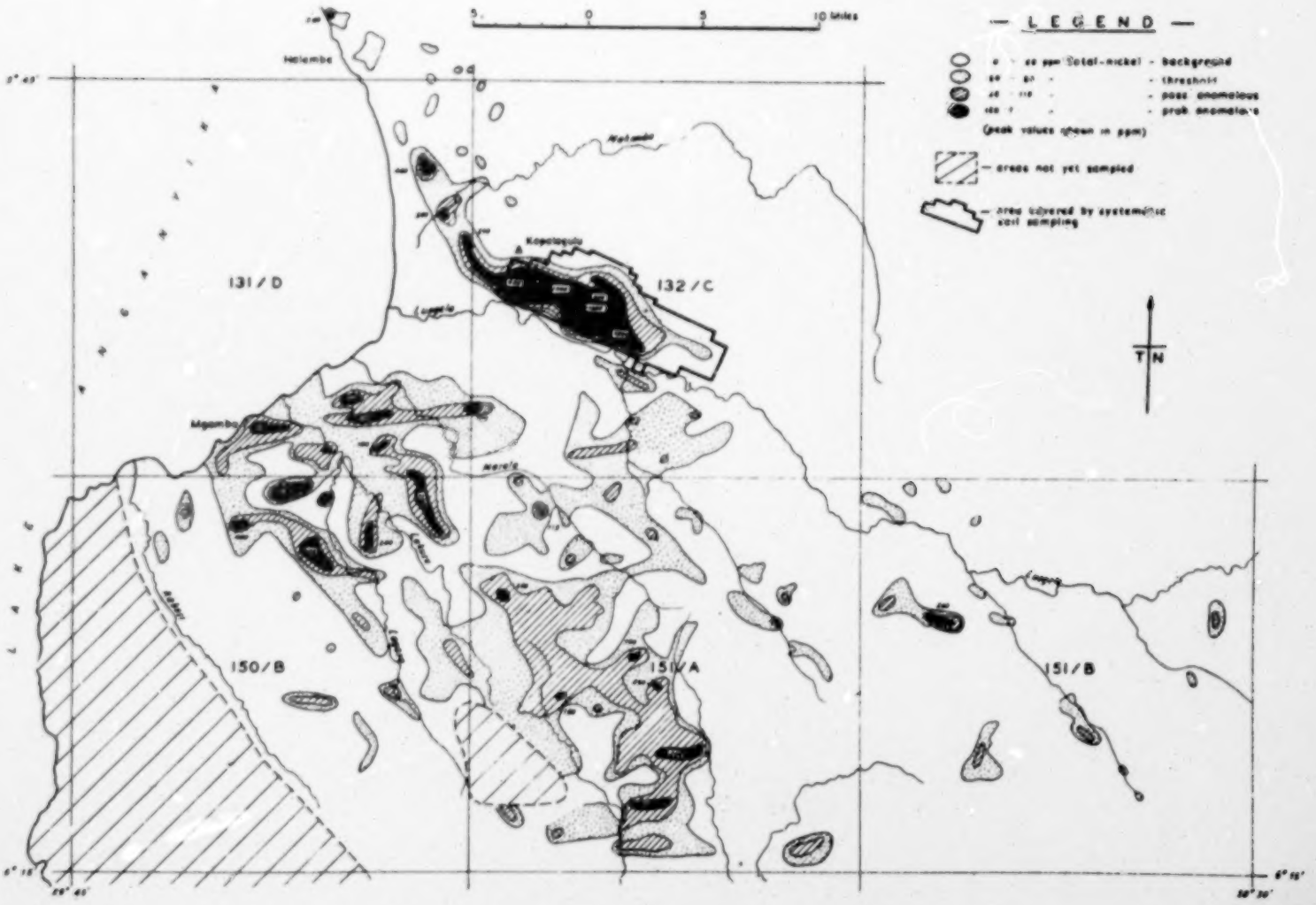

Western Rift Exploration
CHIEF GEOLOGIST
PILOT
ADMINISTRATIVE ASSISTANT
Accounts, Stores
Maintenance, Labour, Office, Traffic
Buildings / Housing, Messing
FIELD GEOLOGISTS
11
GEOCHEMIST
Lab Supervision
Geochemical determinations
PHOTOGEOLOGIST
Compilation of results
Photogeology Geophysical, Geochemical liaison
Geological records
Field Investigation
Drawing Office supervision
MINERALOGIST / PETROLOGIST
Heavy residues
Petrology and Mineralogy
Special duty
MOTOR MECHANIC
Maintenance
FIELD ASSISTANT
General Duty
FIELD ASSISTANT
Roads and Airstrips
FIELD ASSISTANTS
18
DRILLER
LAB ASSTS
2
Garage Hands
Driver
HOUSEKEEPER
Casual Labour
Cooks
Field Labour
Drivers
Tracer
Lapidary
Typist
Cooks
Storekeeper
Labour
Sample Preparers
Domestic Personnel
Assistants
Casual Labour
Assayers

Figure II

AREA KAPALAGULU

DRAINAGE RECONNAISSANCE - NICKEL ANOMALY PLOT



SEPTEMBER, 1960

Figure III

E/CONF.39/A/342
6 Nov.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A. 3. 1. 2

United States of America

EDUCATION IN HYDROLOGY

By John W. HARSHBARGER,
Head, Department of Geology,
University of Arizona, Tucson,
U. S. A.

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

No. 687

A.3.1.2

EDUCATION IN HYDROLOGY

by

John W. Harshbarger
Head, Department of Geology
University of Arizona, Tucson (U.S.A.)

1. The growing importance of development and intelligent management of water supplies for mankind has created an urgent world-wide need for scientifically trained hydrologists.

2. In recent years, many water problems are being amplified by a rise in man's standard of living, increased production of food and industrial products, and settlement of previously undesirable regions. Thus, water problems are directly related to such things as: (1) increase in population, (2) geographic shifting of population centers, (3) more water use per capita, (4) deterioration of watersheds and a decrease of perennial water, (5) pollution of streams and lakes by man's wastes, and (6) occupation of semi-arid regions.

3. But the water challenge is not limited to desert areas. Intensive development in certain areas where water is plentiful has created severe problems. Supplies adequate in past years are no longer usable. Man's occupation in certain watersheds has increased destruction by floods; sediment from increased erosion clogs drainageways; streams and lakes are polluted by industry and cities. In some areas, inadequate drainage and increased salinity have brought about the loss of arable lands.

4. Many of these problems caused by man cannot be solved by the mere application of money, concrete and labor. Throughout the world, sheer lack of knowledge, of understanding, still impedes the making of sound water development plans on a scientific basis. As the competition for known water supplies becomes ever more keen, the deficiency in basic knowledge of hydrologic principles becomes progressively more serious. Today, in the resolution of late-stage water developments, the margin of error permissable in initial stages cannot be tolerated.

5. The production of well-trained hydrologists, therefore, must have high priority throughout the world, if man's hope of obtaining optimum benefit of the water resources available is to be fulfilled.

6. In this effort, colleges and universities have an indispensable role to play, because the kind of broad education needed can be efficiently given only by them, and because of their traditional interest in basic aspects of the sciences. As hydrology is an interdisciplinary science, it requires the talents and skills of a variety of fields. The water specialist must be well trained in mathematics, physics, chemistry, meteorology, geology, hydromechanics, and agricultural sciences. In addition, he must have a knowledge of economics, social sciences, and law. The training of such persons presents difficult problems to the educational institution attempting to design appropriate programs.

7. The importance of research and advanced training cannot be overstressed. Much necessary insight is still to be gained in the many processes of the water cycle. The attraction of talented students to rigorous training programs requires substantial financial assistance; otherwise, the objectives cannot be attained. As many nations experiencing problems in water resources do not have trained hydrologists or educational facilities, international as well as national programs are essential.

8. Furthermore, international cooperation in promoting knowledge of water resources is called for by the very nature of the subject. As R. L. Nace of the U. S. Geological Survey states in his discussion of "A Plan for International Cooperation in Hydrology":1/

> No nation occupies an entire continent. (The subcontinent of Australia is an imperfect exception). No continent has a closed hydrologic system, but each is a part of a global system. Therefore, no nation can learn by itself, within its own boundaries, all that it must know about water and the hydrologic cycle. None can completely learn even its own local water balance within the continental system...Cooperation among nations is required, so the task is international.

THE SCOPE OF THE SCIENCE OF HYDROLOGY

9. The science of hydrology promotes sound economic development by making possible a realistic understanding of man's hydrologic environment. There are many concepts and definitions of hydrology, but one most suitable for our purpose is from Scientific Hydrology, 2/

> Hydrology is the science that treats of the waters of the Earth, their occurrence, circulation, and distribution, their chemical and physical properties, and their reaction with their environment, including their relation to living things. The domain of hydrology embraces the full life history of water on the Earth.

10. Under this broad definition, the science includes understanding of the earth's physical features and the mechanics of its atmospheric systems. Man's social and economic requirements for management of water resources are to be related to the total hydrologic environment.

11. An adequate description of the global water cycle is still needed to define the circulation of water on the earth as a whole. The nucleus of hydrology lies in the earth sciences. The unifying concept is the hydrologic cycle. The cycle begins and ends with the world ocean and involves the transport of water from sea to air, and from air to land. Here, it may be stored for short or long periods, after which it moves in surface streams or through the earth's porous rocks as ground water back to the sea. In this transitional movement, water passes through the gas, liquid, and solid states. It leaves the sea essentially pure, but during its transit dissolves many inorganic and organic compounds as it passes through one or several biological systems. Further, it erodes the earth's rocks, changes the continental profile, and returns to the sea laden with many minerals and with man's wastes. The quantitative water budget of the oceans and continents, and the dynamics of water vapor in the atmosphere, need to be better understood. The horizontal transport of water vapor in the atmosphere as well as the precipitable water must be evaluated to obtain the net influx of water vapor to areas of water need. The water balance of the globe requires more attention than heretofore for the sake of better understanding of the terrestial phase of the hydrologic cycle.

12. There still are major gaps in the basic data necessary to adequately explain the distribution of water on the globe. For example, the magnitude of the North

African aquifer is not known, and as yet no discharge measurements have been made on the Amazon, the world's largest river. There are vast desert, tropical, and polar regions of variable climate for which there are no hydrologic data. Such regions are of tremendous significance for a global analysis of the water budget.

13. As a complement to these physical and biological aspects, the hydrologist should have knowledge of factors that bear on water management. Comparative and quantitative studies of water management techniques, as influenced by climatic variability, water distribution, land use, and economics, are called for. Legal, social and ethnologic characteristics have a large bearing on the devising of acceptable water projects for mankind. Historically, hydrology has been more empirical than theoretical, but the time has come when hydrology must become fully a science.

RECENT DEVELOPMENTS IN HYDROLOGY EDUCATION IN THE UNITED STATES

14. The world over, many programs for improving economic and social conditions hinge on water resources. But the skills to design and manage proposed projects fall far short of the growing demand for them. In the United States, also, despite a long concern for progressive water development, the supply of trained men is inadequate in many respects. In the last several years, many scientists, and governmental agencies in the water field, both state and national, have expressed concern. Only a few educational institutions in the United States have long experience in offering some basic courses in hydrology, which comprise the formal academic training of today's senior hydrologists. Prior to 1960, less than 60 major universities listed hydrology courses in their catalogs and only 14 of these were offered at a graduate level. A special panel on the matter of training reported that, as of 1960 -- there were perhaps only five or six universities which offered anything approaching a program of advanced study in hydrology.

15. In August, 1962, an Inter-University Conference on Hydrology was convened by the University of California, Los Angeles, w/representatives from nineteen universities, eight federal (national) agencies, and the American Geophysical Union. The participants were of unanimous opinion that there is a critical shortage of suitably trained men in all aspects of hydrology and that universities are obligated to develop adequate educational programs. The group also agreed that much more research in the water field at universities is needed to strengthen training programs at the graduate (advanced) level.

16. But even before the Conference expressed this consensus, some half-dozen universities had announced broader programs in hydrology for the 1961-1962 academic year. Most of them are designed for graduate training, and are interdisciplinary in that courses of instruction offered by several departments are integrated. The programs differ somewhat depending upon the advanced degree; the degrees given are usually in a specific departmental area. New techniques in statistics, operations research, and systems engineering are some of the powerful tools which are now being taught. (One university in the southwest, the University of Arizona, offers both undergraduate and graduate degrees in hydrology. An incomplete survey of the courses now being offered in colleges and universities in the United States in given in Annex B.) Requirements for entrance to these programs include substantial background in mathematics, physics, chemistry, hydro-mechanics, and geology.

17. In the academic year 1962-63, other American colleges and universities began to integrate course offerings in the broad field of water resources. Thus, there are now about 20 institutions in the United States which are striving to make hydrology, as a scientific discipline, comparable to other physical sciences. Most of these are state universities located in the western half of the country; others are in the "Middle West" and the coastal areas of the east. This recent intense effort, which benefits from active cooperation among universities, is a significant development in education.

TRAINING FOR STUDENTS OF OTHER NATIONS

18. Many students from other nations are already studying hydrology and related fields in the United States. With the growth of the newer programs described above, more opportunities are becoming available to students from abroad.

19. The study of hydrology, a science that is literally global in scope, calls for international exchange of knowledge regarding one of man's essential resources. Improved educational and training facilities, in the United States as in other countries, will contribute to the better solution of water problems throughout the world.

Annex A. Study in Hydrology and Related Fields at the University of Arizona

20. To provide an integrated program in hydrology in American universities usually requires special interdepartmental arrangements. The experience of the University of Arizona is of interest.

21. This University initiated in 1961 a new program in scientific hydrology which provides broad training in basic sciences and a rigorous synthesis of hydrologic systems. The program includes undergraduate and graduate curricula leading to Bachelor of Science, Master of Science, and Doctor of Philosophy in Hydrology. It includes basic courses in mathematics, physics, chemistry, geology, meteorology, hydromechanics, botony, economics, and social sciences.

22. Eight new hydrology courses at the graduate level deal with scientific principles and systems analyses of the many hydrologic interrelationships. The graduate program is open to students holding degrees in other fields such as civil engineering, geology, soils, meteorology, and agriculture. Prior study in hydrology is not required provided certain requirements are met: Differential equations, general chemistry and physics, physical and historical geology, fluid mechanics, botany or biology, economics, engineering drawing and data analysis, field techniques, surveying and geologic mapping.

23. The hydrology program is guided by a committee of representatives from the participating departments. The committee, acting in lieu of a departmental faculty, recommends acceptance or denial of applications, advises students, develops and approves graduate study programs, approves research topics and directors, and suggests examining committees.

24. In connection with this new program, it is also of interest to mention some other significant activities of the university which concern water resources.

25. The University of Arizona has achieved a recognized position in arid land and water studies owing in part to its location in the arid southwest. Emphasis on teaching and research in hydrology naturally varies from department to department but the exceptional scope of the University's work in this and related fields is seen in activities outlined as follows:

26. The Institute of Atmospheric Physics conducts research in behalf of basic knowledge of the weather and climate of Arizona, of the southwest, and of arid regions of the earth in general. The Institute views the problem of water in an arid land as the fundamental one, and studies aspects such as the regional flux of water vapor, microphysical properties of water particles in the clouds, etc.

27. Many studies relating to water are done in the College of Agriculture. The Department of Agricultural Engineering has collected over many years material of exceptional significance for hydrology, such as full historical records of ground water basins. Closely related to this work is the determination of transmissibility and specific yield of water bearing formations.

28. The Institute of Water Utilization is involved in fundamental and applied research relating chiefly to development, conservation and utilization of water resources under semi-arid and arid climatic conditions. A major subject of research is artificial recharge, related to the ground water supply in Arizona. The Department of Watershed Management is concerned with methods for wildland watersheds which will produce optimum yields of water and other products coincident with satisfactory flood and erosion control. Investigations of transpiration rates of various plants are being made with the aim of manipulating vegetation for maximum water yield.

29. Soil water and water quality are the special concern of the Department of Agricultural Chemistry and Soils. The Department is also conducting research into the movement of water and nutrients through soil and into plants.

30. The Department of Agricultural Economics deals with such matters as the pricing of water, the patterns of watershed development and land use, structures of water law, and water regulatory organization.

31. The interests of the department of Civil Engineering lie in conception, design, construction and operation of water development projects. Recent research includes the hydraulics of long culverts and of partially full flow in conduits of various shapes.

32. The Geochronology Laboratories studies some problems to do with occurrence and movement of water during geologic history.

33. The Laboratory of Tree-Ring Research is an important supporting unit for the hydrology program, with its studies on the relation between environmental parameters and the radial growth of trees. There are strong indications that variations in width of tree-rings reflect variations in precipitation and streamflow during the past 5,000 years.

REFERENCES

1. A Panel of Hydrologists (U.S.A.), A Proposal and Plan for International Cooperation in Hydrology, Bull. Inter. Assoc. Scien. Hydrol., p. 11, v. 6, (1961)

2. Ad Hoc Panel on Hydrology, W. B. Langbein, Chairman, Scientific Hydrology, Federal Council for Science and Technology, Washington, D.C. (June 1962).

Annex B:

Titles of courses in hydrology and closely related areas offered by educational institutions in the United States.

Dealing chiefly with physical factors

*Hydrology
Groundwater hydrology
*Surface water hydrology
*Field hydrology
*Land mass hydrology
*Watershed hydrology
*Hydrologic systems
*Dynamics of flow systems of the earth
*Quantitative determination of aquifer performance
*Geology of groundwater
*Fluid mechanics
*Hydrodynamics
Flow in porous media
Free surface flow
*Hydraulics of open channels
*Hydraulic engineering
Flood control hydrology
*River hydraulics
Water power engineering
Coastal engineering
River-harbor engineering and hydraulics
*Irrigation hydraulics
Drainage of agricultural lands
Seepage and earth dams
*Meteorology
Hydrometeorology
*Physical and dynamical meteorology
*Physical climatology
*Arid zone agroclimatology and micrometeorology
*Physics of soil water
Glacial geology
Permafrost
Fluvial geomorphology
Hydrodynamics of sediment transportation
Limnology
Oceanography
*Water quality and geochemistry
*Quantitative geomorphology
*Analog model analysis of hydrologic systems
*Statistical hydrology
Applied statistics in hydrology
Application of digital computers to hydraulics and sanitary engineering problems

Dealing chiefly with biological factors

*Forest influences on watershed management
*Plant-water-soil relationships
*Dendrohydrology
Hydrobiology
*Water supply and waste water disposal
*Principles of sanitary engineering
Water pollution control
Chemistry of water purification and sewage treatment
Atmospheric pollution
*Industrial wastes
Disposal of radio-active wastes

Dealing chiefly with economic and social factors

*Water utilization
*Appraisal and development of water supplies
Principles of watershed management
*Watershed programs, administration and policy
Wildland hydrology
*Irrigation management and water conservation
Water institutions and economics
Economics of water resources
*Water law
Human ecology
*Land economics

*Courses offered in hydrology programs at the University of Arizona, Tucson.

1655 E - Nov. 1962 - 1,600